The INSTITUTION *of* PRODUCTION ENGINEERS

JOURNAL

(*January* 1944, *Vol. XXIII*, *No.* 1, *Ed. B*)

CONTENTS

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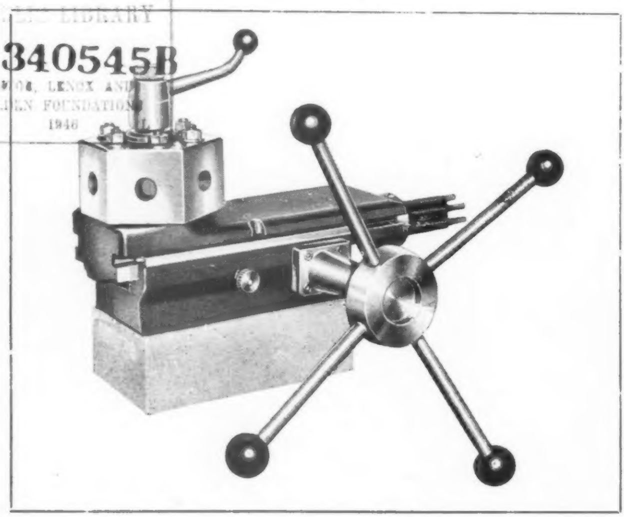

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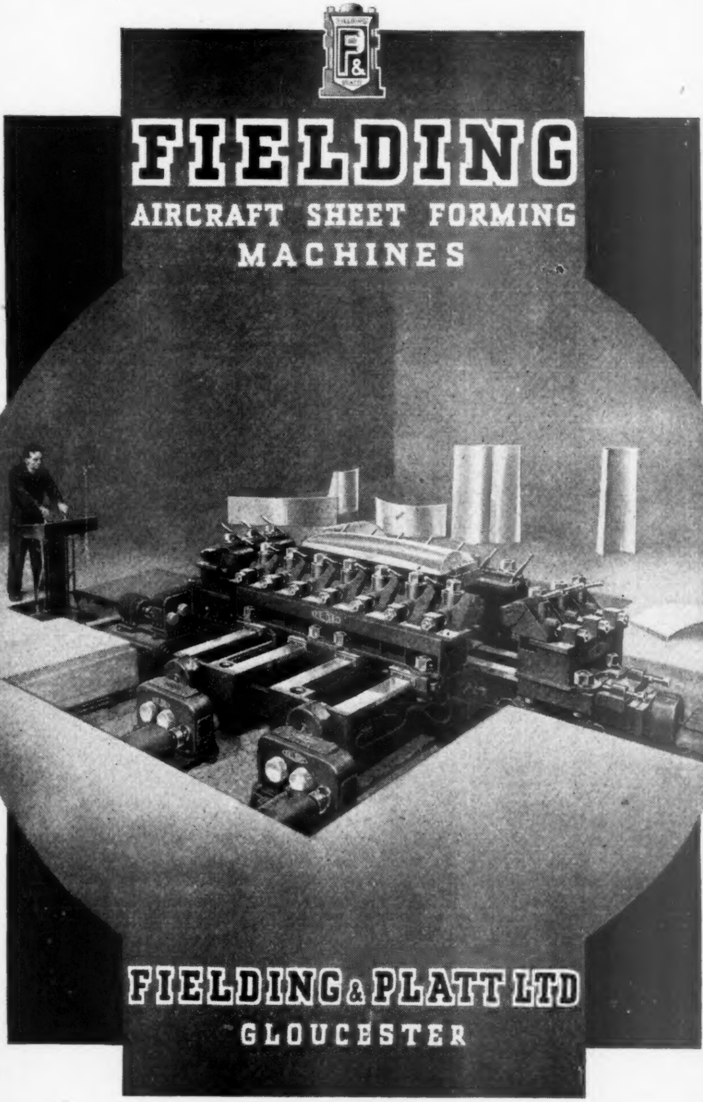
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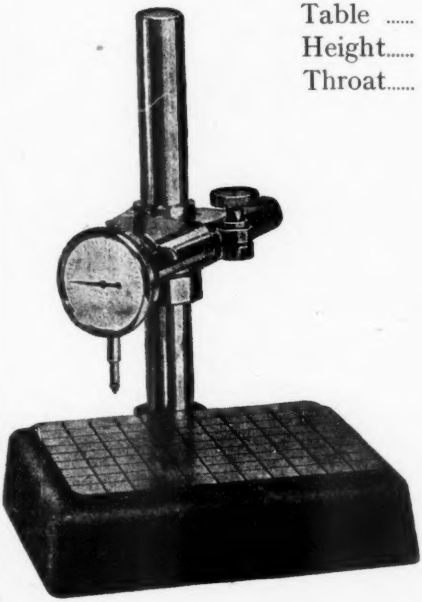

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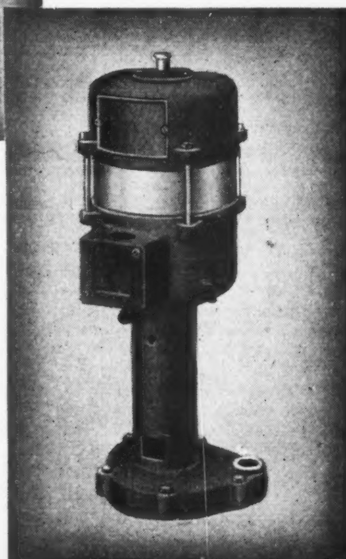

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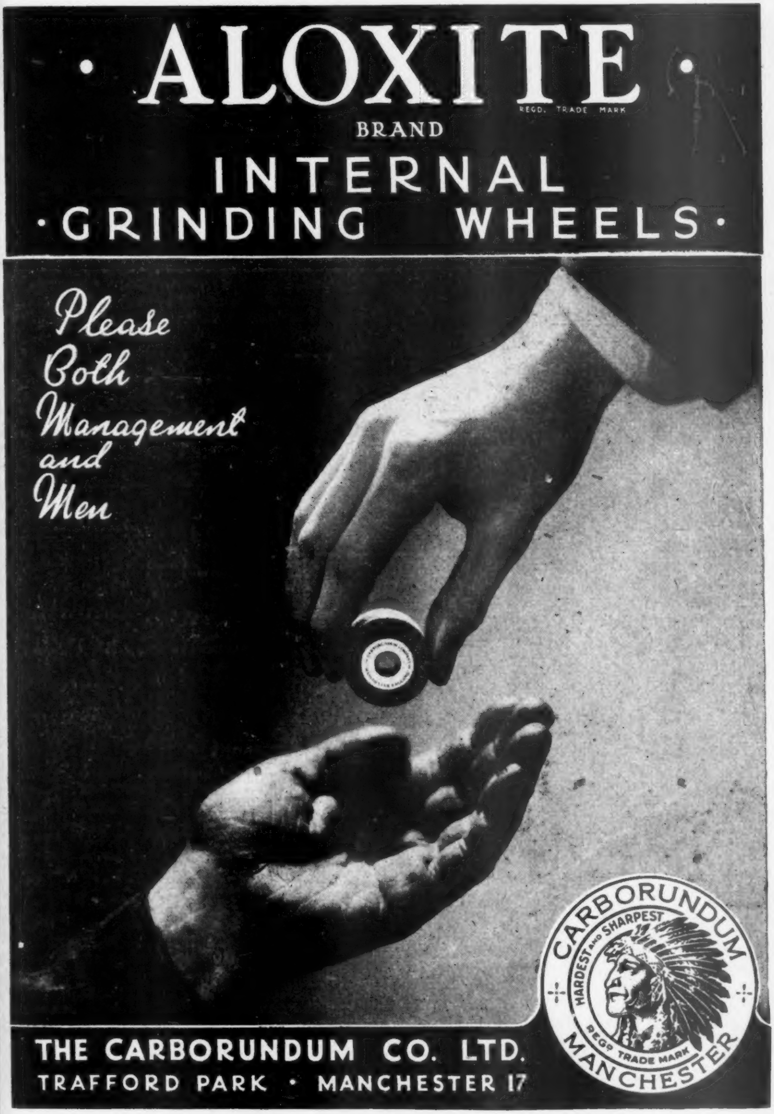
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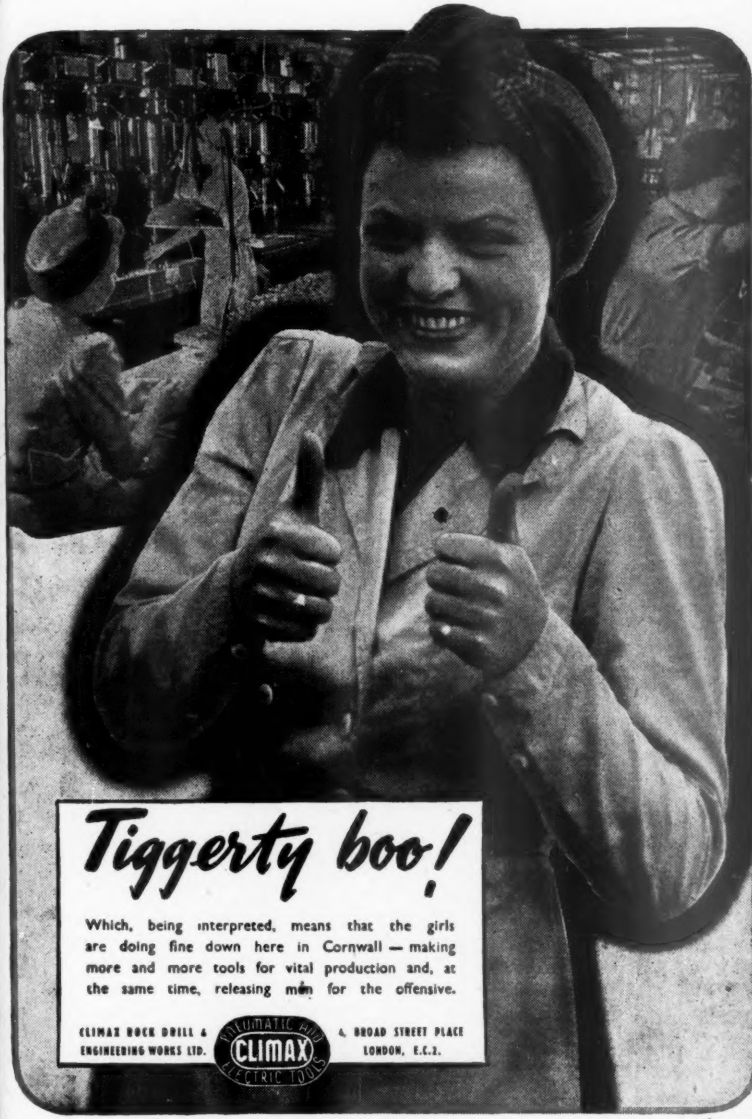
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INDEX TO ADVERTISEMENTS

As a war-time measure the advertisement section of this Journal is now published in two editions, A and B. Advertisers' announcements only appear in one edition each month, advertisements in edition A alternating with those in edition B the following month. This Index gives the page number and edition in which the advertisements appear for the current month.

The fact that goods made of raw materials in short supply owing to war conditions are advertised in "The Journal" should not be taken as an indication that they are necessarily available for export.

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1943-44

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Loughborough College : T. D. Walshaw, B.Sc., Loughborough College, Loughborough, Leics.

INSTITUTION NOTES

January 1944

Extraordinary General Meeting.—Official Notice.

NOTICE IS HEREBY GIVEN that an Extraordinary General Meeting of the Institution will be held at Institution Headquarters on Friday, 18th February, 1944, at 2-0 p.m., for the purpose of ratifying the Council's recommendation that membership subscriptions be increased as follows :—

	Present Subscription			*Proposed Subscription*		
	£	s.	d.	£	s.	d.
Full Member	2	10	0	3	3	0
Associate Member	2	0	0	2	12	6
Intermediate Associate Member ...	1	11	6	2	2	0
Associate	2	0	0	2	2	0
Graduate (over 25 years)	1	10	0	1	11	6
Graduate (under 25 years)	1	0	0	1	1	0
Student (over 25 years)	1	0	0	1	1	0
Student (under 25 years)		10	0		10	6

BY ORDER OF THE COUNCIL

K. G. Fenelon,
General Secretary.

February Meetings.

4th February—London Section. At the Institution of Civil Engineers, Great George Street, London, S.W.1., at 7-0 p.m. An informal discussion on " Rate Fixing and Time and Motion Study " will be opened by A. E. Young, Esq., A.M.I.P.E.

4th February—Coventry Section. An " Any Questions " evening at the Coventry Technical College, at 6-45 p.m.

4th Febrary—Eastern Counties Section. A " Question Night " on Production Engineering subjects in the Lecture Hall, Museum, High Street, Ipswich, at 7-0 p.m.

4th February—Lincoln Sub-Section. At the Technical College Lecture Hall, Lincoln, at 6-30 p.m. A. Chisholm, Esq., (Halifax), will lecture on " Jigs, Tools, and Workshop Methods."

7th February—Coventry Graduate Section. At the Coventry Technical College (Room A5), at 6-45 p.m. " Case discussion-"

11th February—Nottingham Section. A meeting will be held in tne Staff Canteen of Crossley Premier Engines Ltd., Sandiacre, Notts., at 6-45 p.m. An informal discussion on " Inspection," will be opened by A. Johnstone, Esq., M.I.P.E.

11th February—North Eastern Section. The County Hotel, Newcastle-on-Tyne, at 6-15 p.m., W. H. Curtis, Esq., will lecture on "Costing as Applied to Production."

12th February—Preston Section. At the New Technical College, Manchester Road, Bolton, at 2-30 p.m. H. W. I. Inshaw, Esq., will lecture on "Plastics."

12th February—Yorkshire Graduate Section. At the Hotel Metropole, Leeds, at 2-30 p.m. F. W. Berridge, Esq., will lecture on "Excavating Machinery." This will be a joint meeting with the Graduate Section of the Institution of Mechanical Engineers.

18th February. Extraordinary General Meeting of the Institution at 2-0 p.m. at 36, Portman Square, W.1.

18th February—London Graduate Section. At 36, Portman Square, London, W.1, at 7-0 p.m., A. Risik, Esq., will lecture on "Quality Control in Production."

22nd February—Sheffield Section. At the Royal Victoria Hotel, Sheffield, at 6-30 p.m., Mark H. Taylor, Esq., M.I.P.E., will lecture on "Some Applications of Optics to Engineering."

24th February—Leicester Section. At The College of Technology, The Newarke, Leicester, at 7-0 p.m., N. R. Bligh, Esq., B.Sc., and S. V. Williams, Esq., B.Sc., will lecture on "Heat Treatment by High Frequency Inductance."

24th February—Glasgow Section. At the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2., at 7-15 p.m. Dr. H. Orenstein, M.I.P.E., will lecture on "The Importance of the Activities of the Production Engineer in Post-War Conversion."

24th February—Manchester Section. At the Technical College, Manchester, at 7-15 p.m. Professor T. H. Pear will lecture on Morale in industry."

26th February—Yorkshire Section. At the Hotel Metropole, Leeds, at 2-30 p.m. E. A. Cooke, Esq., will lecture on "The Grinding of Profiles."

27th February—Luton Section. At the Luton Library Meeting Room, George Street, Luton, at 10-0 a.m. R. T. Rolfe, Esq., F.I.C., and J. R. Boyant, Esq., B.Sc., of W. H. Allen, Sons & Co. Ltd., will lecture on "Failures of Design and Material."

Committee Meetings, etc.

1st February—Special Meeting of Membership Committee at Queen's Hotel, Birmingham, 11-30 a.m.

8th February—Special Meeting of Education Committee at Queen's Hotel, Birmingham, 11-30 a.m.

18th February—London Section Committee Meeting at Institution Headquarters, 12-0 noon.

18th February—Meeting of the Finance and General Purposes Committee, at Institution Headquarters, 2-15 p.m.

21st February—Meeting of the Finance Committee of the Research Department, at Loughborough, 2-15 p.m.

22nd February—Meeting of the Education Committee at Queen's Hotel, Birmingham, 10-0 a.m.

22nd February—Meeting of the Membership Committee at Queen's Hotel, Birmingham, 12-30 p.m.

The Technical and Publications Committee meets at Headquarters every Wednesday, at 5-30 p.m.

Council Meeting.

The next meeting of the Council will be held on Friday, 24th March, at Loughborough, at 11-30 a.m.

Halifax Section.

A new section is being formed at Halifax, but the date of the inaugural meeting has not yet been fixed.

Newly Elected Members.

As Members: J. T. Ball, P. Bevan, A. H. Blackwell, V. Bleasdale, R. Cairns, H. Dowell, C. D. Gibb, Major Hon. O. M. Guest, H. W. Harper, W. Langford, J. A. Leech, W. P. Meeson, T. H. W. Millie, J. Murphy, R. S. Odd, D. D. Rayner, W. R. Snell, H. C. Yaffe.

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As Associates: G. E. Bache, W. M. W. Brunyate, E.. A. Hyde T. L. Morton, A. Siddall, J. Stokes.

As Intermediate Associate Members: V. J. Adams, J. W. A. Aldridge, J. H. Allen, R. E. Andrews, G. E. Bateson, W. J. Baxter, J. H. Bodinetz, A. E. I. Bond, W. J. Brambley, W. E. Challinor, W. S. Cuthbertson, L. W. Davies, R. Davies, E. Dawson, C. R. Devlin, G. E. Dodd, A. R. Ellis, A. H. Evans, G. Forrest, W. S. French, J. E. Fry, S. Giles, G. C. H. Guard, P. G. Hewitt, F. Heywood, J. R. Hicks, B. G. Hockridge, J. C. Holmes, A. L. Ireland, F. Ives, H. M. James, F. A. Janes, T. A. Johns, R. E. Jones, R. G. E. Jones, H. Kay, C. W. H. Long, D. A. Loydall, R. McMillan, W. A. Mackrow, G. A. Maisey, A. J. Mantell, A. Osgerby, A. D. Pead, W. G. Remington, T. B. Roberts, V. E. Rogers, S. R. Rose, A. Sadler, H. Sampson,

A. Smith, A. E. Smith, J. M. Steer, E. A. Westwood, A. G. Williams, A. Williamson, E. Woolley, L. W. Worthington, S. Wright.

As Graduates: E. H. Arnold, G. W. Clamp, D. Coates, J. H. Cotton, A. D. Edwards, E. Griffin, M. W. Hibling, M. H. Horton, J. H. Kellner, R. H. H. Kingdon, S. J. Martin, V. Morley, G. T. Price, C. Toeman, R. A. Ward, J. W. Wong Yen.

As Students: T. C. Allen, W. Ayres, R. Barker, J. D. Bond, G. W. Brown, K. L. Carpenter, D. A. Chappell, J. A. Cleal, M. A. Cook, D. Cullern, R. Day, L. M. Harman, L. J. Harrow, R. H. Hodges, J. H. Hull, G. F. Lloyd, S. E. Lofthouse, F. G. McCormick, D. J. Main, M. F. Mansell, K. L. Merther, C. F. Millington, E. R. Newell, D. W. Pain, J. A. Pickford, R. H. Poole, J. E. Pretty, K. Pridding, F. W. Rodgers, C. T. Rushton, C. W. Smith, R. J. K. Snell, C. N. Taylor, F. I. Thomas, W. J. Vaughan, W. Venables, J. A. Walford, P. J. Welburn, N. F. Whitehead, R. Willcock, A. P. Williams, R. S. Williams.

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Transfers.

From Associate Member to Full Member: A. L. Asquith, F. T. Daniel, E. S. Gregory, C. R. Jordan, E. Paton, Major E. Smith, J. B. Stevenson.

From Intermediate Associate Member to Associate Member: W. Cookson, C. J. Kneller, N. E. Langdale, E. G. Milner, F. H. Schofield, T. J. Tilley.

From Graduate to Associate Member: W. H. Cross, L. C. Carr-Locke, M. Z. Rivlin, W. A. Robinson.

From Graduate to Intermediate Associate Member: F. Hine, W. Howells, L. Hutchinson, J. Hutchinson-Jarvis, J. Reid, E. Southam, J. Tocher, G. E. Trotter.

From Student to Graduate Member: H. Derbyshire, B. A. Gittens, W. Johnson, K. C. Morgan, N. Newey, S. J. Rice.

Honours List.

Members will have seen from the New Year's Honours List that Mr. G. E. Bailey has been awarded a Knighthood for the invaluable service he has rendered to the engineering industry. Sir George Bailey is the immediate Past President of the Institution having held the Presidency from 1939 to 1942.

A. V. Allday and I. S. Sinclair receive the M.B.E. in recognition of their services to production, and we offer to these three members our sincere congratulations on the honour conferred upon them by His Majesty.

Dr. Schlesinger.

On 21st January last, Dr. Schlesinger celebrated his seventieth birthday. We extend to him our best wishes for an improvement in his health in the near future.

Appointment of Deputy Director.

We have much pleasure in announcing that Dr. D. F. Galloway, B.Sc., has been appointed Deputy Director of the Research Department. Dr. Galloway has for the past four years been assistant to Dr. Schlesinger at the laboratory. We wish him every success in the increased work and responsibility which he is undertaking.

Higher National Certificates in Production Engineering.

We have been informed that the following candidates, who sat for the Higher National Certificate in Production Engineering, have successfully passed the examination :

Birmingham Central Technical College : G. A. Bentley A. G. Bradbury, H. S. Butcher, J. L. Gwyther, W. H. Gwyther, N. Newey, E. R. Nicholls, C. A. Rawes, R. J. Read, R. P. Sampson.

Derby Technical College : G. F. Allen, E. A. Bradley, E. H. Cutts, H. Derbyshire, T. R. Fletcher, R. E. Gell, G. R. Gibson, V. C. Harrison, B. Johnson, D. Lacey, D. A. W. Leech, W. J. Murfin, C. S. Petrie, W. A. Reeves, D. M. D. Scott. G. P. Torrance, A. York.

Keighley Technical College : H. G. Bottomley, W. Stalker, H. D. Wharton.

The Northampton Polytechnic Institute, Finsbury : M. R. Carson, R. Cescotti, A. C. Clerk, W. P. Collier, R. V. Dowse, P. S. McCaig, R. T. Mustard, J. E. Poulter, B. L. Steward.

Wolverhampton and Staffordshire Technical College : M. A. G. Andrews, R. Cooper, W. G. Evans, J. W. Hallam, E. C. Horton, K. C. Morgan, A. G. Welch.

Subscriptions.

Members who have not yet paid their annual subscription are reminded that the financial year commences on 1st July of each year. The prompt payment of subscriptions considerably facilitates administrative work and obviates unnecessary expense and use of paper.

The Technical Bulletin.

The attention of members is drawn to the fact that as from December, 1943, publication of the *Technical Bulletin* has been discontinued. This decision has been accepted with reluctance after careful consideration of all the circumstances.

THE PRODUCTION OF SURFACE FINISH

Paper presented to the Institution, Yorkshire Section, on 2nd October, 1943, by J. L. Hepworth, Grad.I.P.E., B.Sc. (Eng.)

WE have heard a great deal lately on the question of surface finish, and its measurement, and much valuable work has been done to enable the quality of a certain surface to be expressed in definite and universal terms, which can be understood and reproduced. Where previously the quality of a surface has been judged by eye, in comparison with an accepted standard, instruments have now been developed and are in regular use which can trace out the contour of any given surface on a greatly magnified scale and indicate the depth and pitch of the surface irregularities. A figure is also given which represents the average height of the irregularities, and is generally expressed in millionths of an inch (or microinches), yet in spite of these measurements it is not sufficient to specify the surface characteristics in figures only. The method by which the surface is produced is very important. Two surfaces giving the same value of surface roughness produced by different methods can give entirely different results under working conditions.

It is intended to discuss very briefly the various machining methods employed for producing surface finish upon metallic materials. Such methods can be divided into two major classes :

Chipless methods which do not definitely remove material, but rely more upon a pressing or flowing action of the surface material to produce the shape desired.

Chip methods which produce surface and dimension by the definite action of a cutting tool, be it a single-point tool or a multipoint abrasive tool.

Examples of the chipless methods are, casting, coining, cold heading, forging, pressing, rolling, burnishing. Broadly speaking these methods are used only for operations where close dimensional accuracy is not required, and as preliminary operations to the chip forming methods. An exception is the case of burnishing, which is used as a finishing operation after turning, grinding or boring. Its action is to bring about a flow of the surface layer by non-elastic deformation. If a surface is accurate and rough, the resulting surface, after burnishing, will be accurate and smooth. However

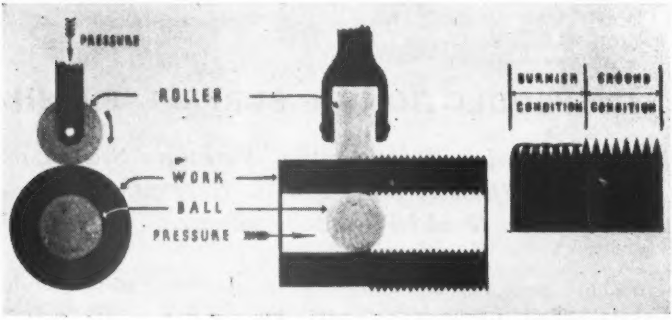


Fig. 1.

if a surface is inaccurate and rough the resulting surface will be inaccurate though smooth.

A burnished finish on outside diameters is not generally extremely accurate as the pressure varies according to the strength of the centres and the holding device on which the burnishing is performed. There is also sufficient displacement of the grain and molecular structure of the surface material, so that burnishing produces a surface composed of material above the base material which ordinarily is not satisfactory for heavy bearing loads and high speed operation.

Internal burnishing is more common, and an example of this is the burnishing of valve guides by pressing through the hole a hardened steel ball. In such a case the bearing load is small and the operation has the following functions :—

1. Smooths the surface giving a highly reflective finish.
2. Impregnates the surface with lubricant, provided lubricant is used in the operation.
3. Hardens the extreme outer layers of the metal.

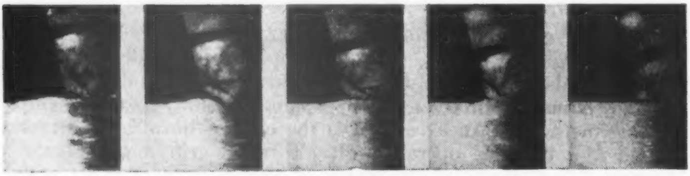


Fig. 2.

For the production of accurate surfaces the chip-forming methods are more frequently used, the commonest of which are :—

(a) Turning, boring, planing, shaping, slotting.
(b) Milling, broaching, filing, sawing.
(c) Drilling, reaming, tapping.
(d) Grinding, honing, lapping, superfinishing.

Basically all the above processes are the same in principle, consisting of a shearing action of the metal by the tool, the tool being harder than the material to be cut.

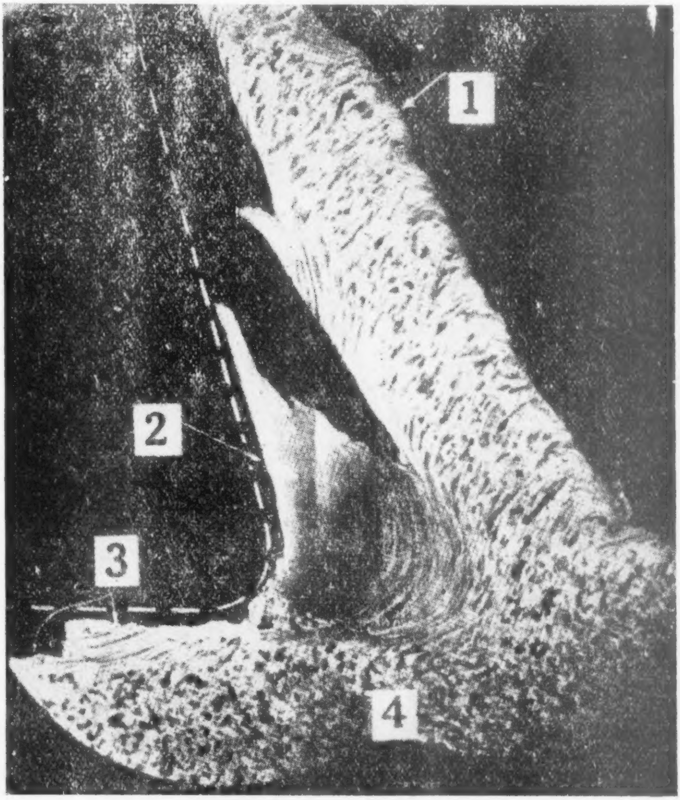


Fig. 3.

Single-point turning is the basic method, the others being variations in its application. Let us therefore consider the actual conditions which make up the turning method of surface finishing.

The removal of metal is effected not by a true cutting action, but by a tearing or shearing away of the metal. By using the high speed motion camera it has been possible to study the exact process of this shearing. It becomes apparent from photos so obtained that the shearing does not take place at the cutting edge of the tool, but that under the extreme pressure of the cut, a fragment of metal becomes welded to the tool tip and acts as a wedge in shearing the metal above it. This wedge is known as the " built up edge." As the stationary pile of compressed material becomes larger and larger the line of shear between itself and the ship body on the one side, and the workpiece on the other moves farther and farther away from the cutting edge. Thus, as the built up edge increases in size, it also becomes more and more unstable; eventually a point is reached where failure occurs and fragments are torn off and escape with both chip and the workpiece.

This intermittent building up and breaking down of the forward end of the built up edge occurs at an extremely rapid rate, thus the

Fig. 4.

surface of a workpiece finished under these conditions is covered with a multitude of fragments of built up edge.

Examination of a tool tip which has been used for cutting steel or aluminium frequently shows the remains of a built up edge welded on to it.

Photomicrographs have been taken of a chip in the process of forming by stopping the machine suddenly, leaving a partly formed chip (Fig. 3). Thus the built up edge can be seen to be composed of compressed material, and the surface of the workpiece leaving the tool is in a distorted state, the crystalline grains of the material being elongated in a direction substantially parallel to the tool face. With steel, and other ductile materials the chip is continuous, but the underside shows the remains of a multitude of built up edges (Fig. 4). Brittle materials break up as the tool bends the chips off, but cast iron in addition cuts freer as the built up edge has less tendency to weld through lubrication by the graphite in the material.

Naturally this continual tearing away of the metal generates a great amount of heat as a result of the following major causes :—

A. Molecular flow and grain movement setting up tremendous internal friction with resulting heat.

B. By the pressure of the chip moving across the surface of the tool, depending upon the coefficient friction between the chip and the tool, and the cutting speed.

C. By friction of the workpiece against the clearance edge of the tool.

The first has been shown to be the greatest source of heat rise. Use of correct tool rake keeps it to a minimum.

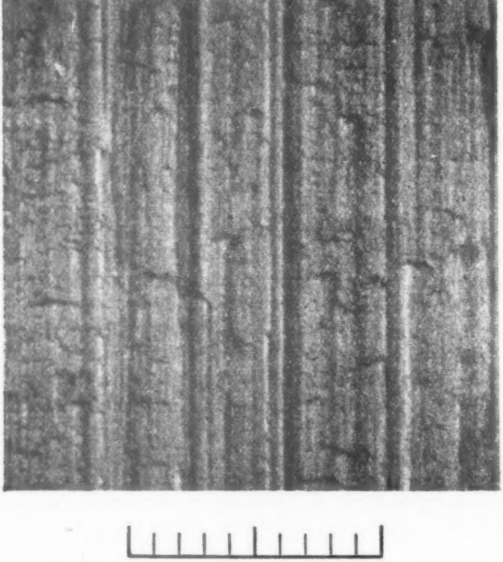
The second can be reduced by keeping the top surface of the tool smooth, and by using a cutting lubricant to cause the chip to slide easily.

The third is normally relatively unimportant, but if the cutting edge breaks down a fairly large area of the tool will rub against the workpiece causing excessive heat rise followed by complete breakdown of the tool.

Because of this heat generated fluids are run on to the tool to act as coolants. They are necessary because excessive heat causes breakdown of the cutting edge of the tool, resulting in reduced efficiency, also to cool the part being machined in order that dimensional accuracy may be maintained.

For a good finish the surface must not be produced under extremely high temperature conditions which might be conducive to grain growth, fragmentation of crystalline material, distortion of molecular structure and the formation of smear or amorphous metal.

In considering the turning operation mention has been made of the high surface speed, tool pressure, the high temperature produced, the method by which the material adheres to the face of a turning tool and is forced through the material being pushed ahead, the splitting off of the material ahead of the actual tool and the dis-



One inch = .040 inch

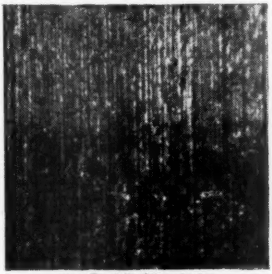
PHOTOMICROGRAPH OF SURFACE

Part	Armature shaft
Material	Steel
Operation	Turned .016 feed
Profilometer	250 microinches rms.
Magnification	25 diameters
Illumination	Oblique

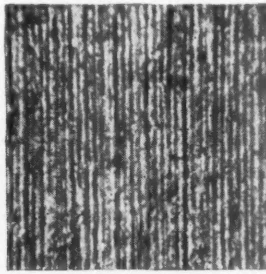
Fig. 5.

rupting of the crystalline structure of the material. It is, therefore, not surprising to discover that, in a surface produced by turning, not only are the extreme outer layers of the surface, but many layers beneath are subjected to tremendous elastic and non-elastic deformation and molecular disturbance. (Fig. 5).

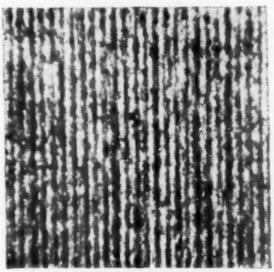
The extreme outer layers composed of irregular peaks and valleys are made up of material which has been pulled, pushed, squeezed, melted, fragmented, torn and otherwise mutilated. Beneath the outer layers are inner layers serving as a bond to hold the outer layers to the body of the part. The inner layers have been disturbed



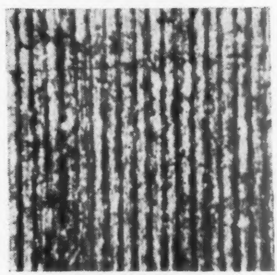
.001 Feed Per Revolution
40 Microinches rms.



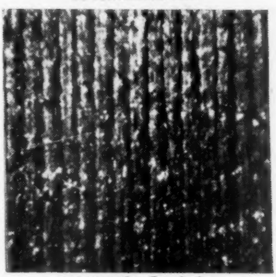
.002 Feed Per Revolution
50 Microinches rms.



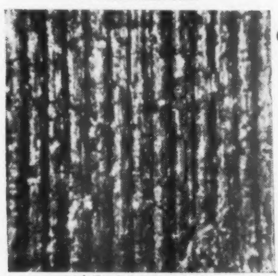
.003 Feed Per Revolution
80 Microinches rms.



.004 Feed Per Revolution
100 Microinches rms.

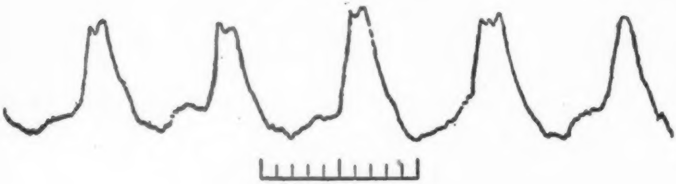


.005 Feed Per Revolution
80 Microinches rms.



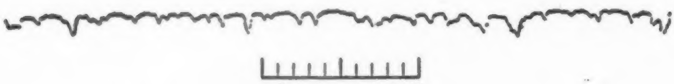
.006 Feed Per Revolution
100 microinches rms.

Fig. 6.—Precision bored Surfaces.



One inch = .033 inch

PROFILOGRAPH OF A ROUGH TURNED SURFACE



One inch = .033 inch

PROFILOGRAPH OF A FINISH TURNED SURFACE

Fig. 7.

be elastic and non-elastic deformation, stressed and compressed and otherwise mutilated in much the same manner as have the outer layers except perhaps to a lesser extent.

Beneath these outer and inner layers is the undisturbed body of the material, an orderly crystalline structure.

It is thus very clear that turned surfaces are not conducive to carrying maximum loads with minimum friction.

The depth of the disturbed outer layers will naturally depend upon the nature of the operation. In rough turning operations with a very heavy cut it will be a maximum and will be clearly visible to the naked eye. Using modern well-designed high speed lathes taking a very light cut at fine feed it will be at a minimum. The best example of this is diamond tooling. To the naked eye this appears as a very bright, smooth surface, but under a microscope the hills and valleys are observed and the surface roughness can be seen.

Tooled finish is employed in quite a number of cases as a bearing surface, chiefly in non-ferrous holes such as gudgeon pin holes in automobile pistons. (Fig. 6 and 7).

The essentials for good results are :

(a) *Fine feed*—in order of .0005 in. to .005 in. per rev.

(b) *High spindle speed*—for free cutting and to make for economical running.

(c) *Design of machine.* The spindle must be a first class rigid job. A well designed plain bearing spindle can be used or if ball or roller bearings, the races must be special precision races. Good balance is essential with no vibrations. It goes without saying that the slides must be in good order without any play, and the feed drive must be perfectly smooth. Hydraulic feed is recommended. The tool holder must be as rigid as possible, and with a

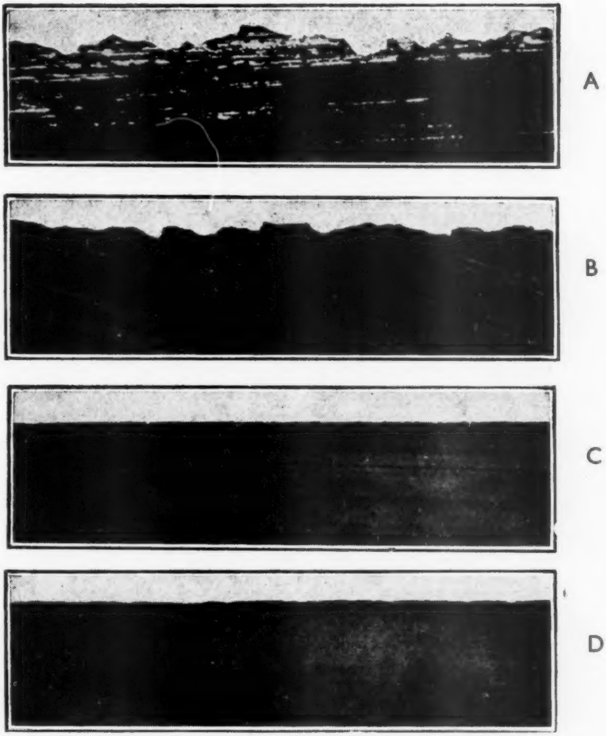


Fig. 8.

(a) Cemented carbide cutting tool rough ground.
(b) Cemented carbide cutting tool finish ground.
(c) Cemented carbide cutting tool ground with "Spedia" wheel.
(d) Ordinary razor blade (for comparison purposes).

boring bar keep the diameter as big and the length as small as possible.

(d) *Tool.* The tool radius is important. Too small a radius leaves a rough finish with well defined feed lines. Too large a radius increases tool pressure and causes chatter. .020 in. to .030 in. R. is best for most jobs.

Tool material should be cemented carbide or diamond. The latter gives a finer finish but easily snips through careless handling or encountering a hard inclusion.

Carbide tools need careful preparation. After rough grinding on a green grit wheel they must be finished on a diamond lap. (Fig. 8). It goes without saying that the correct rakes and clearances must be used.

With free cutting tools and a very fine cut the degree of surface disturbance is at a minimum and such surfaces give very good results in bearing applications.

Burnishing of a turned surface smooths out the peaks and valleys by plastic flow, leaving a bright finish, but still leaves underneath the disrupted metal.

All the remarks regarding turning apply equally well to such operations as boring, planing, shaping and slotting as the method of metal removal is indentical. Drilling, reaming and tapping are similar operations to boring, but multiple cutting edges are used, and the cutting tool is piloted on the surface just machined. This generally gives a burnished effect and an apparently smooth surface.

In milling a multiplicity of turning tools are used, each presenting itself in turn to the workpiece. In addition to the normal surface roughness produced by a single tool, milling produces a further surface irregularity through the discontinuity of the various cuts.

Broaching again uses multiple cutting faces, but in this case each tooth takes a continuous cut over the full length of the surface. Theoretically a broach is an ideal metal removing tool, as each tool can be designed to fulfill a special purpose and that purpose only. Thus the first few teeth on the broach are roughers and take a fairly heavy cut. The later teeth take a very light cut for sizing and obtaining a good finish. In some cases the last few teeth are designed as burnishers and have no cutting edge.

From the surface finish point of view broaching still has the same disadvantages of surface fragmentation, but lacks the feed lines of turning and teeth marks of milling.

Abrasives.

The use of abrasives for the commercial production of surface finish is a comparatively recent development. It first became essential when hardened steel components came into use and,

because of distortion and scaling in the furnace, inaccuracies of a component prior to hardening resulted. Now, of course, abrasive methods are used for finishing hard and soft surfaces on account of the high quality surface and dimensional accuracy of these later methods.

Generally abrasives may not be thought of as cutting tools, and yet when their abrasive action is analysed, abrasives are found to perform in much the same manner as a single point tool performs. Each tiny abrasive grain will act in its own small way as does a single point tool in a multiple milling cutter.

Abrasives may be used loose, as coated abrasives or as bonded abrasives.

Loose abrasives are used only for lapping and polishing operations and the abrasive is mixed with some oily substance and generally charged on to a soft material such as cast iron or wood as a carrier.

Paper or cloth coated with abrasive grains and bonded with a suitable binder can be used for polishing operations where a bright finish is required. Polishing or sanding irregular sufaces such as automobile body sheet metal is a major use for abrasive paper.

Perhaps the most widely used abrasive for commercial surface finishing is the bonded abrasive. This is made up of a base or binder in which is mixed a specific type and size of abrasive grain. This material was carefully mixed. moulded into shape and sintered into a conglomerate whole. It can then be used for any abrasive cutting operation inasmuch as the grains are held in the bond which serves as a toolholder. Each abrasive grain becomes a minute single point tool.

The earliest known abrasives were natural stones found in various localities. These stones, after their cutting or abrading properties were discovered, became of great value to mankind. Some natural formations were found from which large blocks could be obtained, and these were dressed into wheel shape and used as grindstones. The only use these days for grindstones is in rural districts. The natural stone was not fast cutting enough for modern industry and also could not be turned at high speed without danger of the wheel flying to pieces. However, natural stone could be crushed, and the abrasive grain thus obtained moulded into the desired shape. Later, methods of manufacturing artificial abrasives were perfected, permitting accurate control of the finished product. Both natural and artificial abrasive materials are extensively used in industry.

Natural abrasives are : Sandstone.
Solid quartz.
Emery.
Corundum.
Diamond powder.

Artificial abrasives are : Aluminium oxide (which is the cutting element in emery and corundum).
Carbide of Silicon (or carborundum).

Carborundum is nearly as hard as diamond. Aluminium oxide is slightly less hard, but tougher, and the grains are best for grinding materials having high tensile strength.

Specifications of Bonded Abrasives.

Bonded abrasives can be specified by their grain ; bond and structure.

Grains are graded by sieving through a series of screens with so many holes per linear inch. Both aluminium oxide and silicon carbide grains are standard is screen sizes from 4 to 240 and have classified flow sizes of 280, 320, 400, 500 and 600.

A grain of 16 grit will pass through meshes having 16 meshes to the linear inch, but will not pass through the next smallest screen which has 20 meshes to the linear inch.

An abrasive wheel made of grains of one size is termed a straight grain wheel. It is this type that is most universally used by modern industry for precision mass-production grinding operations.

The cutting grains in a grinding wheel must be held together in a suitable manner. The material holding these grains in the form desired is referred to as a bond.

By use of different bond materials or bonding processes the cutting action of grinding wheels can be controlled in order to grind various materials in the most efficient manner. This has resulted in considerable research as to which types of bonding can be best used for different work, however, the greatest proportion of grinding wheels are produced by either of three bonding processes. These are :—

Vitrified (probably 50% of the total).
Silicate.
Elastic (either resinoid, rubber or shellac).

Vitrified bonded wheels are the most widely used type for all purpose grinding. Silicate bonded wheels are smooth and cool in operation, but are not as free cutting as vitrified. They are more generally used for sharpening H.S.S. tools.

Elastic bonded wheels have a number of uses, chiefly as narrow cutting-off wheels, control wheels for centreless grinding, or in cases of producing very bright surfaces.

The specification of structure or hardness of a grinding wheel is always somewhat of a mystery to the uninitiated, being generally expressed by a letter of the alphabet. Confusion is increased, however, by different wheel manufacturers commencing their grades from the opposite ends of the alphabet. Thus while most manu-

facturers specify A as their softest wheel and Z as their hardest, one or two work the other way.

The expressions " hard " and " soft " are themselves misleading in their applications to grinding wheels, for in actual fact the hardness of the cutting grains is the same. It is the strength of the bonding material that is the important factor. A " soft " wheel has a relatively small ratio or bonding material to abrasive, and consequently the abrasive grains are only loosely held together and give a fairly open and porous structure. A " hard " wheel has a high ratio of bond to abrasive and the grains are very firmly held together. Thus we are able to reconcile the well known fact, which is not at first apparent, that a soft wheel is necessary for grinding a hard material and vice versa. Each abrasive grain being a minute cutting tool, cuts a minute chip out of the work, and in so doing gradually becomes dulled, and, in the case of a very hard wheel, would soon cease to cut, merely glazing the surface. What actually happens in the case of a correctly working wheel is that as soon as the grain becomes dulled it is loosened in its bond and broken away, revealing a new grain below to take its place.

Thus, too hard a wheel unless frequently trued will cease to cut, producing high temperature, glazing and sometimes causing surface cracks. A soft wheel will be free cutting, but will soon lose its size and will also produce a poor finish due to the breaking away of the abrasive grains.

It is interesting to consider theoretically the number of cutting points in operation during a grinding process. Consider the case of a wheel 20 in. dia. × 6 in. wide giving a wheel area of 378 sq. in. Assuming the grain size is 100, there will be approximately 10,000 grains per square inch, or 3,780,000 in operation over the whole surface. If tl e cutting speed is 6,000 ft./min. the cutting points in use per min, are 4,320,540,000.

The grinding process is a sizing operation as well as a surface finishing operation, and it is now quite common practice to grind cylindrical articles on production lines to a tolerance of .0001 in. and a surface finish of 5 micro-in. R.M.S. For such results very close attention must be paid to the following points :

Wheel speed.

Work speed and rate of feed.

The lubricant or coolant that is used.

The choice of grinding wheel.

The condition of the grinding machines.

Wheel speeds for efficient use are between 5,000/10,000 ft./min. with vitrified wheels, and 6,000 ft./min. is the normal figure. Increasing the wheel speed has the effect of hardening the wheel.

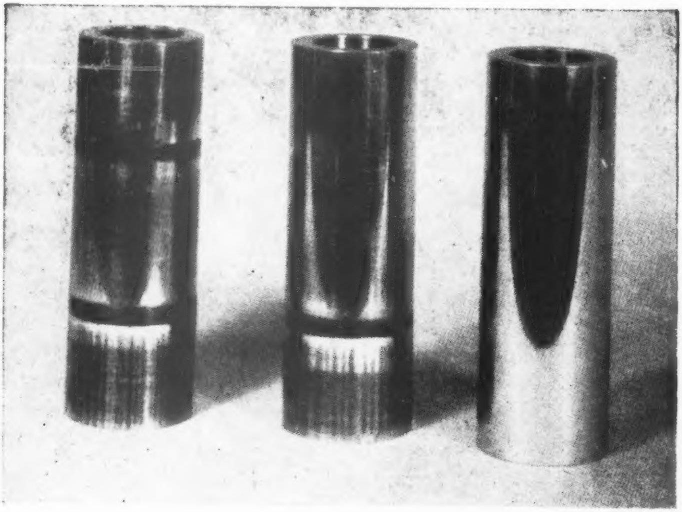


Fig. 9

Work speed should be 30/90 ft./min. for steel, and 200/400 ft./min. for cast iron, but no firm figures can be given as each job must be treated on its own merits.

As in turning operations the use of a coolant-cum-lubricant is important for good surface finish, but much more care is necessary in its use.

Very high surface temperatures are produced in grinding and a flood of coolant is necessary to keep the workpiece cool for dimensional reasons, and also to prevent burning.

The type of coolant used depends upon the material being ground, but for all-round work a soluble oil is very staisfactory. A very important point is that the coolant should be kept clean, as particles of grit in suspension cause marking of the work, and sometimes chatter, especially in the case of centreless grinding. For this reason large settling tanks should be used for the coolant and for high class work a filter is necessary.

The choice of a grinding wheel is a matter of experience, and intelligent trial and error. For rapid stock removal a fairly soft and coarse wheel is best, but gives a poor surface finish. Conversely a hard, fine wheel is not free cutting and rapidly glazes. Consequently for high class work it is general to rough out within a few

thou. of size with a free cutting wheel ; and to finish with a wheel as fine and as hard as possible to give maximum surface smoothness consistent with economical production time and lack of wheel glazing.

The condition of the grinding machine is of first rate importance. It is obviously impossible to produce a first class article unless the machine is carefully adjusted and maintained.

Trouble due to the machine shows itself not only in the surface finish, but in chatter and out of roundness of the workpiece. The

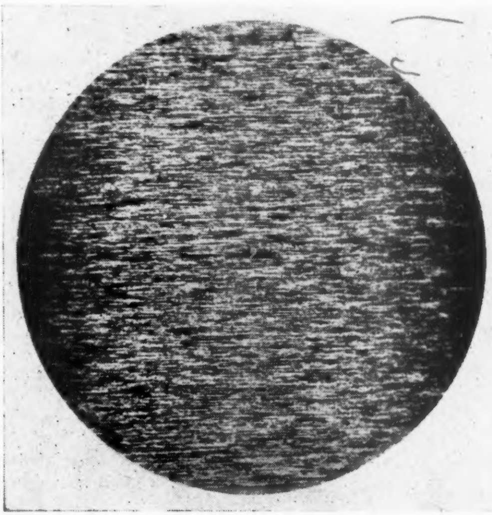


Fig. 10.

best check for this is to rub the ground component with a split brass bush, when every irregularity is revealed. This test will show fine chatter not measurable under ordinary instruments, but which nevertheless are detrimental to a highly loaded bearing surface. (Fig. 9).

Type of Surface Produced.

As previously stated, it is quite common practice to produce a surface finish of 5 micro in. by grinding. (Fig. 10). These surfaces appear extremely smooth to the naked eye and are free from a definite scratch pitch, but it should always be remembered that

grinding cannot be performed without intense surface temperatures, and as in turning the surface layers are torn, crushed and generally mutilated. The temperatures are higher than in turning, but on account of the very light cut taken the depth of the disturbance is not as great. Recent experiments with the electron diffraction camera have shown that a fine ground surface is made up to a depth of 80 atoms of loose fragments of oxides, nitrides and decarbonised metal ; and up to a depth of 50,000 atoms is in a strained condition due to excessive temperature.

This disturbed layer, commonly known as grinding fuzz, is obviously not a good bearing surface and it is common knowledge that this surface must be rubbed off before a bearing can settle down. The process of running-in is a generally accepted procedure. The glazed finish produced by using a very hard wheel, or by " slow wheel " grinding is very smooth, but is actually a foil made up of crushed and melted surface metal. The cohesion of the underlying metal and this amorphous layer will be very weak allowing portions of the smear metal to flake off and wear under any normal bearing load or flexure.

Lapping.

Lapping is essentially a method for producing extremely smooth surface finish, and for making extremely small amounts of correction for accuracy. Abrasive paste, formed by mixing loose abrasive flours with oil, is applied by means of a lapping shoe, quill, or similar unit, which is of softer metal than the work to be lapped. Usually the area of the lap is relatively high in relation to the work area.

As compared with bonded abrasive, there is no definite area of contact. Cutting action is accomplished by the comparatively few grains which become charged, or embedded, in the soft metal lap. Normally, a very large number of grain particles, roll loosely between the surfaces of the work and the lap, producing a rubbing, lightly burnishing action. Consequently, the distribution and number of these cutting contacts varies constantly in operation.

The total normal pressure used in lapping is mechanically applied, and is extremely low. Unit pressures, however, may vary from high to relatively high, depending upon the combined characteristics of the charged grains as related to the bridging effect of plug type lapping application.

The lapping members are actuated in combinations of rotary and stroking motions over the work surface. This actuation more readily permits the grits to embed themselves into the lapping member. Also, when embedded, it serves to accomplish more efficient cutting action, by fracture of the grains, or by allowing all cutting edges of the grains to work. The characteristics of a lapped surface is its multi-directional cutting marks.

The process is capable of generating surface planes accurate within a few millionths of an inch, and surface smoothness of less than 1/10 millionth of an inch. Its applications cover all types of surfaces, whether cylindrical, flat, internal or external. In certain cases, notably valve seats, a component may be lapped to fit its mating component.

It will be appreciated from the preceeding remarks that the success of hand lapping depends entirely upon the sklil of the operator and is a very slow process. While it is not to be improved upon for accuracy of surface contours it is not a production process, but the engineer has been able to reproduce the characteristics of hand lapping in a machine. Originally Johansson lapped his gauge blocks by hand, but we owe their widespread use as reference gauges to the lapping machines which make their large scale production possible.

There is nothing very elaborate about a lapping machine—in fact one could build several for the cost of one plain grinding machine. Generally it consists of a cast iron table approximately 2 ft. by 3 ft. in diameter which rotates slowly in the region of 100 r.p.m. Above this is a similar table, kept stationary and capable of being lowered onto the work which is placed between the tables and held in a carrier. This carrier is given an eccentric movement in relation to the table. Pressure is applied to the work by the weight of the top plate or by other controllable means. A supply of abrasive and lubricant is applied periodically to the plates. Size is controlled purely on a time basis, the experienced operator knowing how long it will take to remove the desired amount of stock. It is absolutely essential that the lapping plates are perfectly flat, and this is usually done by lapping them against each other.

Lapping machines were originally developed by flat surfaces, but are frequently used for cylindrical work, in which cause the abrasive is only in line contact with the work. On account of this errors such as chatter and out of roundness from previous operations cannot be corrected.

A further refinement in recent years has been the replacement of the cast iron plates by fine abrasive wheels both of which rotate in opposite directions but at slightly different speeds. Very high grade surfaces are produced by this method.

Honing.

This process cannot be better described than by quoting L. S. ·tz, of the Micromatic Hone Corporation :—

"he honing process originated in the demand for a better method ıcing smoother surface finish in bores than could be obtained ely by earlier forms of grinding or reaming operations. ı efficiency of mechanical output increased, the process

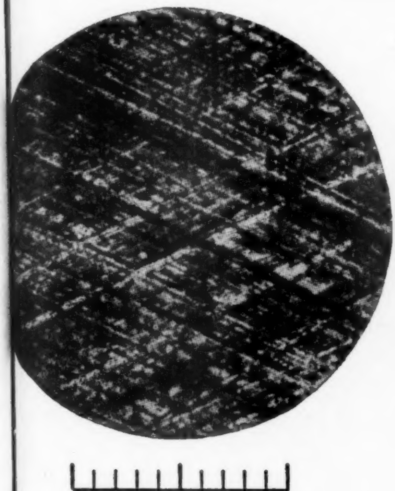
developed controls to correct errors and produce low tolerance accuracy for roundness and straightness. With the expanding trend towards metal treatments, and exaggerated heat treating distortions, further developments and controls have been provided to increase the rate and the amount of stock removal by 1200 to 1400% of that formerly obtained. It has also developed external applications on some cylindrical parts.

"Honing uses the largest contacting abrading area, as related to work surface, of any of the abrading processes. It uses both silicon carbide and aluminium oxide only in stick form, and in grain sizes from approximately 80 to 600. Bonds used, particularly on steel parts, are usually soft. For example: In a bore 3 in. diameter by 8 in. long, six 150-grit stones would have an area of 7.5 square inches of contacting abrasive area, and an estimated 98,000 odd simultaneous sheering contacts. A corresponding grinding wheel application, using a 46 grit wheel, would have approximately .055 square inches of contacting abrasive area and only about 48 simultaneous shearing contacts. In other words, honing would have over 2100 times as many simultaneous shearing contacts as compared with grinding.

"The total normal pressure used in honing, while higher than that used in other abrading processes, results in unit pressures ranging from approximately 55 to 75 lbs. per square inch in rough honing, and from 40 to 55 lbs. per square inch in finishing honing. With so many simultaneous contacting grits, this means that unit pressure per grit ranges from .324 to .019 ounces in rough honing and from .015 to .003 ounces in finish honing. Grinding would generate up to approximately 5000 times as much pressure per grit in medium rough grinding and up to 30,000 times as much pressure per grit in finish grinding.

"In present actuations honing uses simultaneous combinations of rotation and reciprocation of the abrasive, and sometimes rotation or reciprocation of the work, depending upon the nature of the result desired. A number of different types of surface finish markings result from these actuations, comprising regular and irregular mechanical patterns of abrasive travel, as may be desired to conform with functional operation of the surfaces. These multi-directional motions serve to control the degree of cutting action, and the type and degree of surface finish desired.

"The speeds used in honing are relatively lower than in any other mechanically operated abrading process which uses bonded abrasive. The abrasive is rarely actuated in production faster than 250 surface feet per minute. In the majority of applications this speed rarely exceeds 200 surface feet per minute.



PHOTOMICROGRAPH OF SURFACE

Part	Bearing race
Material	Steel
Magnification ...	25 diameters
Illumination	Oblique

PHOTOMICROGRAPH OF SURFACE

Part	Bearing race
Material	Steel
Magnification ...	25 diameters
Illumination	Oblique

Fig. 11.

"Honing produces combined accomplishment. It corrects error, and generates form accuracy within tolerances as low as .0001 in. in some parts and up to .001 in. in others, depending upon the size and characteristics of the application. It generates uniform size well within the practical production limits required for the majority of interchangeable parts. It is capable of removing substantial amounts of stock—at the rate of 57 cubic inches per hour—to compensate for unusual errors and distortions resulting from heat treating or previous processing. It generates any type of finish desired to meet functional operating requirements of assembled parts. It generates any degree of surface finish smoothness desired in production processing.

"Honing has been generating so-called commercial finishes ranging from 5 to 10 micro-inches, r.m.s., and very smooth surface finish within 1 to 5 micro inches, r.m.s., in regular high production for approximately the past eight years, in many cast iron and steel parts." (Fig. 11).

While honing will correct surface and size defects of previous operations it will not correct errors of alignment of the hole.

The honing head consists of a number of abrasive sticks (usually six or eight) equally spaced radially which are capable of being expanded outwards. This movement controls the rate of stock removal and size and can be done by hand or automatically. To this head is imparted a rotating and reciprocating movement. generally paraffin is used as a lubricant. (Fig. 12).

In one stroke of the conventional honing process the cutting grains travel a very considerable distance in their helical path without a

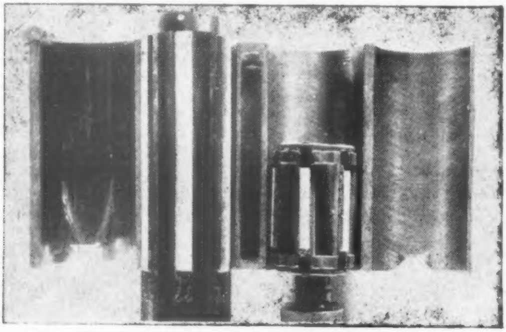


Fig. 12.

change of direction. Thus the grits tend to become blunted and to give a glazing effect, giving an apparently good surface.

Recent developments have tended to increase the number of movements so that the stones are constantly changing their direction. Thus they remain free cutting under lower pressures and generate less heat.

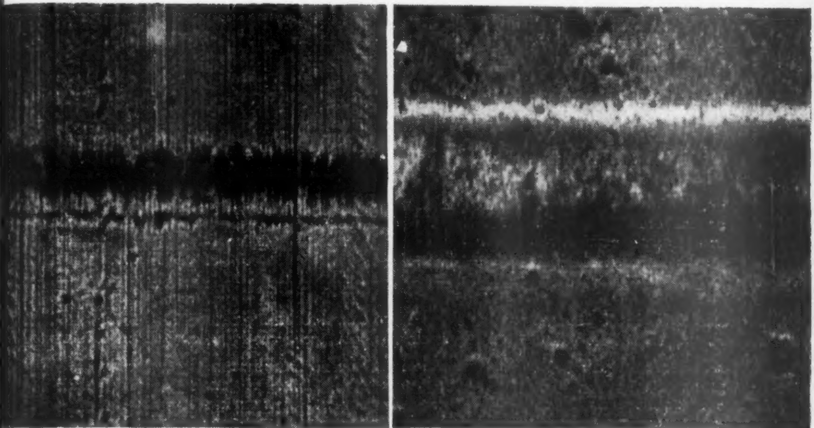
The " Microfinishing " process employs a fairly rapid and short reciprocation of the hone or work piece in addition to the normal movements.

Superfinishing is based upon the same principles.

Superfinish.

This is a trade name given by the Chrysler Corporation to a new technique for obtaining a very high surface finish on a mass production basis.

The development of this process commenced some years ago when it was discovered that harmful brinell marks were made by the



One inch = .040 inch

PHOTOMICROGRAPH OF SURFACE

Part	Cylinder bore
Material	Cast iron
Operation	Honed
Profilometer	29 microinches rms.
Magnification ...	25 diameters
Illumination	Oblique

One inch = .040 inch

PHOTOMICROGRAPH OF SURFACE

Part	Cylinder bore
Material	Cast iron
Operation	Honed
Profilometer	29 microinches rms.
Magnification ...	7 diameters
Illumination	Oblique

Fig. 13.

rollers on roller bearing races in the rear axles of cars shipped across the U.S.A. by rail. These marks were small in themselves when examined after shipment, but in service soon enlarged producing noise and eventual bearing breakdown. (Fig. 13).

Amongst the explanations put forward to explain these indentions were that of corrosion, the effects of electrolysis, etc. However, it was demonstrated that lapping would remove the infinitely thin "fuzz" which it was discovered, was what really had been indented or brinelled from the pounding effect produced by the railway trucks on the rails. The base metal was unaffected. The superfinish process was first developed to remove this fuzz, and completely overcame the trouble. It has now been applied to a much wider field.

While superfinishing is not yet in widespread use in this country,

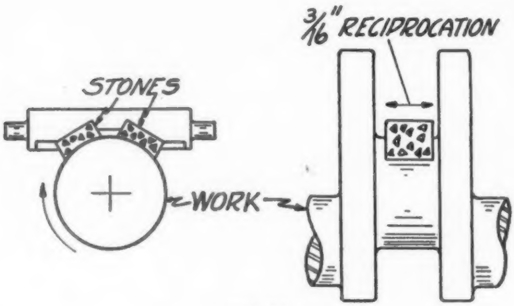


Fig. 14.

it is used on a large scale in the U.S.A. This is how A.M. Swigert of the Chrysler Corporation describes the process.

" Superfinishing technique uses relatively coarse bonded abrasives, a combination of short scrubbing motions, light pressures, slow abrasive cutting speeds, and a fluid acting as a lubricant instead of a coolant. The resulting surface is different metallurgically and

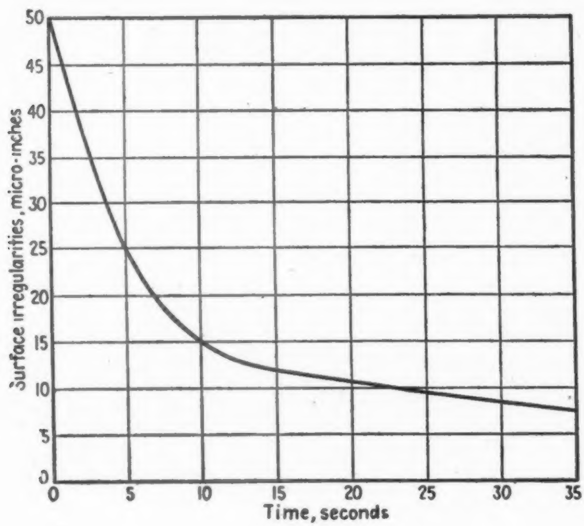
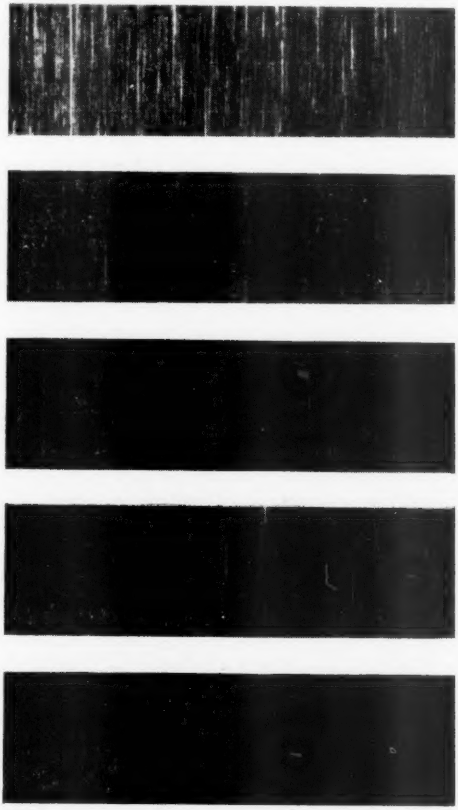


Fig. 15.

physically than surfaces produced by any other commercial machining method. Abrasive stones, held lightly against the work, move back and forth, while the work spins, revolves or oscillates in such a way that surface "teeth" and "peaks" left after grinding are scrubbed away.



SECTION ONE
Ground
65–75
Microinches rms

SECTION TWO
SUPERFINISHED
5 seconds
30–35
Microinches rms.

SECTION THREE
SUPERFINISHED
10 seconds
14–18
Microinches rms.

SECTION FOUR
SUPERFINISHED
15 seconds
10–12
Microinches rms.

SECTION FIVE
SUPERFINISHING
Completed
1–2
Microinches rms.

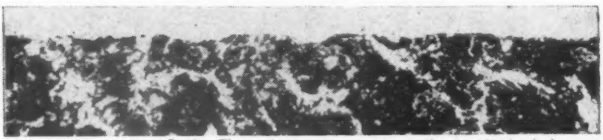
One inch = .040 inch
Magnification ....25 diameters
Illumination ....Oblique

Fig. 16.—Progressive Superfinishing—surface photomicrographs of test bar.

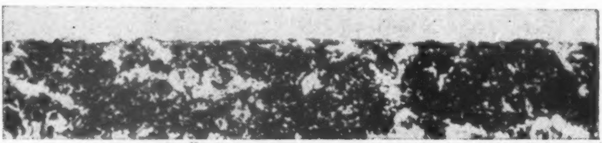
" Mechanical operations that are performed to obtain dimensional size fragmentize the metallic surface of the part so there is left a surface that by anology may be compared to a layer of snow upon a body of ice. The snow is of exactly the same chemical composition as the ice but in an entirely different physical condition. Likewise

Section One—Original Ground surface; 65–75 microinches rms.

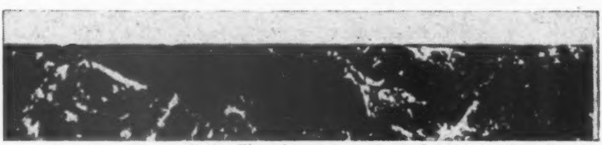
Section Two—SUPERFINISHED 5 seconds; 30–35 microinches rms.



Section Three—SUPERFINISHED 10 seconds; 14–18 microinches rms.



Section Four—SUPERFINISHED 15 seconds; 10–12 microinches rms.



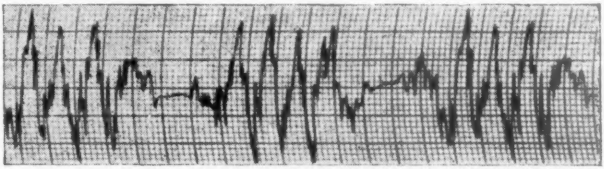
Section Five—SUPERFINISHING completed; 1–2 microinches rms.

One inch = .0013 inch

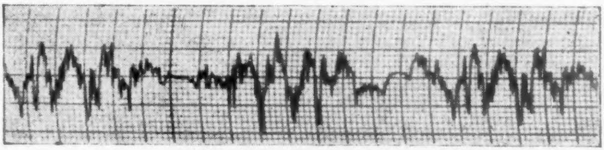
Magnification ....750 diameters

Fig. 17.—Profile photomicrographs of test bar.

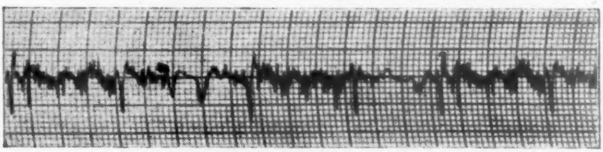
a block of steel that has been finished to dimensional size will be covered with amorphous metal. This surface can be brought to a superfinished surface with a bonded abrasive brick by removing the fragmented material leaving the smooth crystalline surface exposed.



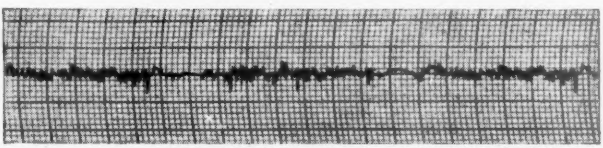
Section One—Original Ground surface. 65–75 microinches rms.



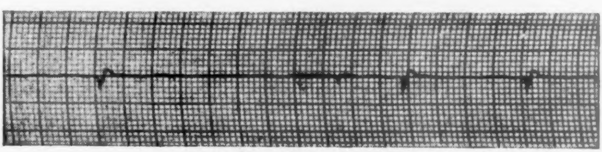
Section Two—SUPERFINISHED 5 seconds; 30–35 microinches rms.



Section Three—SUPERFINISHED 10 seconds; 14–18 microinches rms



Section Four—SUPERFINISHED 15 seconds; 10–12 microinches rms



Section Five—SUPERFINISHING completed: 1–2 microinches rms

Magnification—Vertical 3900x; Horizontal 20x.
Each small square = 10 millionths inch vertically

Fig. 18.—Surface analyzer charts of test bar.

"One of the basic advantages of superfinishing is the rapidity with which rough surfaces produced by other methods are smoothed in a few seconds. The greater percentage of surface roughness is removed in the first 5 seconds of the operation. As the bearing area increases, the loaded stone, and lubricant viscosity begins to take effect. This slows up material removal which insures an increasingly mild abrasive action."

The fundamental of superfinishing is that the stone should never travel the same path across the work more than once. This is obtained by using a combination of motions such as the following: (Fig. 14).

The abrasive stone is oscillated $^1/_{16}$ in. at 500 r.p.m. making 1,000 strokes per min. of $^1/_{16}$ in. each. The mechanism oscillating the stone at this rate is itself oscillated $\frac{1}{4}$ in. at 100 r.p.m., making a motion of 200 $\frac{1}{4}$ in. strokes. In addition the whole mechanism slowly traverses to and fro along the whole length of the work piece which is also rotating slowly. The combination of these

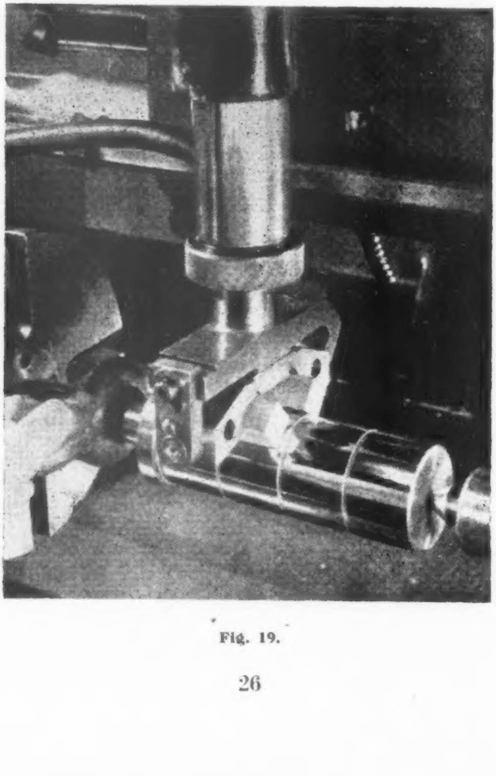


Fig. 19.

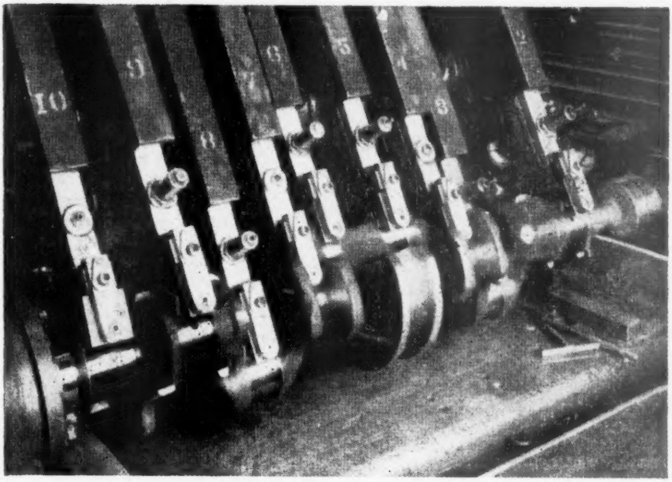


Fig. 20.

four movements gives the stone a random movement never repeating the same path and which, as anyone who has done any hand lapping knows, produced the smoothest surface in the shortest time. (Figs. 15, 16, 17 and 18).

Superfinishing can be applied to any shape of surface and is not restricted to cylindrical work, and also lends itself to use on special purpose machines for mass production. (Figs. 19, 20 and 21).

Comparison of Types of Surfaces.

In comparing these various methods of surface finishing it must be borne in mind that two things are generally aimed at in metal removal, viz.—dimensional accuracy and surface finish. Turning is primarily a stock removing operation, while at the other end of the scale superfinishing removes practically no metal at all (i.e. only several $\frac{1}{10,000}$ in. at the most).

It will be obvious that the more metal removed at a cut, the greater is the heat generated and the more fragmentation of the surface occurs. For this reason it is good practice always to remove metal in two or more stages, the last stage being a very light cut. (Fig. 22).

One failing of the grinding process is that as the grains break

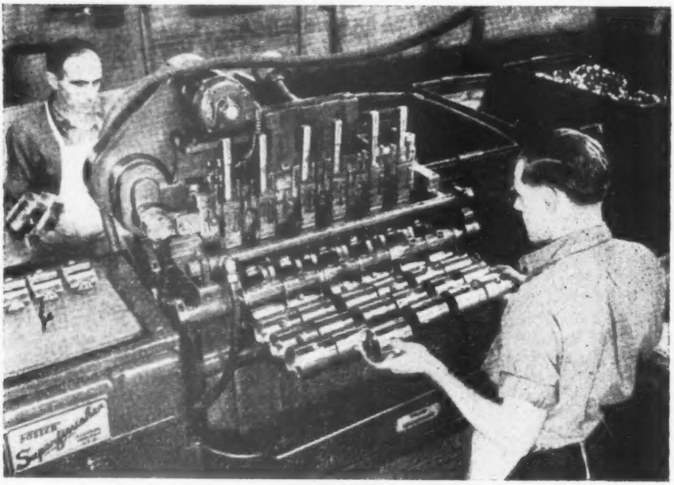


Fig. 21.

away from the wheel, some fragments of them are embedded into the surface of the workpiece. Whether this occurs enough to cause trouble is debatable, but it is realised that it is bad practice to lap soft materials with loose abrasives. It is claimed that with superfinishing, pressures are so low as to prevent this occurring. (Fig. 23).

With some trepidation I would now like to discuss the thorny problem of how smooth a surface should be. A high degree of finish is desirable generally for one or more of the following purposes:

(a) Pleasing appearance.
(b) Reduction of fatigue.
(c) Bearing purposes.

Fig. 22.

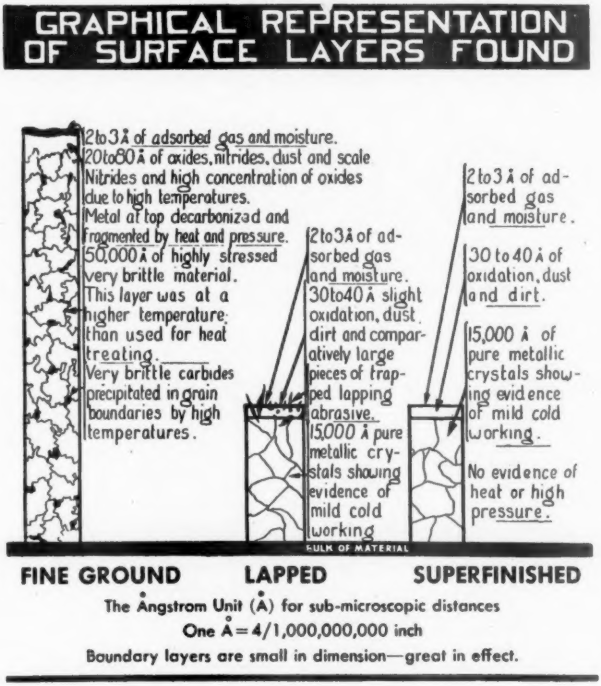


Fig. 23.

The first needs no discussion beyond mentioning in passing that hand-lapped and superfinished surfaces do not appear as smooth to the naked eye as fine ground surfaces of the same roughness, on account of the random appearance of the scratches.

In regard to fatigue, it has long been acknowledged that a good surface increases the fatigue range, for two reasons. A very rough surface is in effect covered with a series of sharp notches which result in high stress concentrations causing cracks which gradually spread across the member. Secondly if it has been produced by a heavy cut the metal is disturbed for some considerable depth below the surface and will again give rise to cracks when highly stressed. It does not appear necessary, however, to go to very fine degrees of finish unless the component is severely stressed.

It is the question of bearing surfaces that I want to discuss more

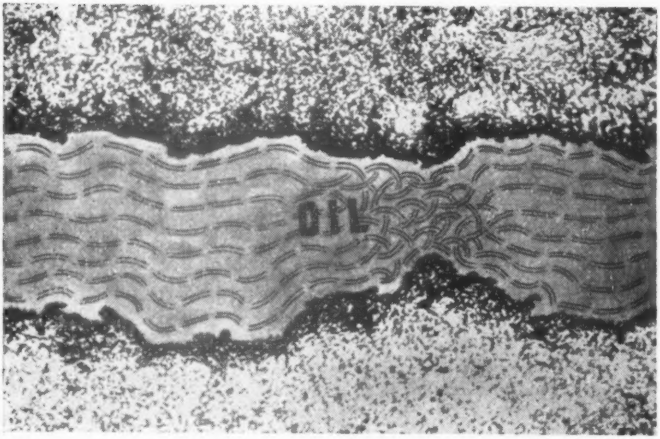


Fig. 24.

fully, and it is here that we come up against controversial ideas. It has been a recognised practice in fitting a bearing to make it a tight fit and to allow it to run itself in—always a painful procedure. During this running in period high spots are removed and the bearing clearances increased to what is agreed to be the normal amount. What happens during this running period ? A glance at tracing of a ground surface shows it quite clearly. The surfaces are covered with a thin layer of rough fragmented material whose high spots penetrate the oil film in the bearing and are torn off. This process proceeds until the surfaces rub each other smooth. The results are quite satisfactory provided sufficient heat is not generated to cause seizure, in which case the bearing would be ruined, and that the loose material removed is not allowed to circulate with the oil and cause continuous wear. By this method the onus for a successful bearing is placed upon the user. In the case if a soft metal running against a hard metal the loose fragments will become embedded in the softer metal and acting as a lap will wear away the harder surface.

Arguing on these lines one school of thought says " Why not remove all this fragmented metal before assembling the bearing ? Then no running in period will be required, and the bearing will have a longer life." Superfinishing is recommended for removing the high spots. The graphs show that it is advantageous in levelling off the high spots, yet retaining to a greater or less degree the hollows

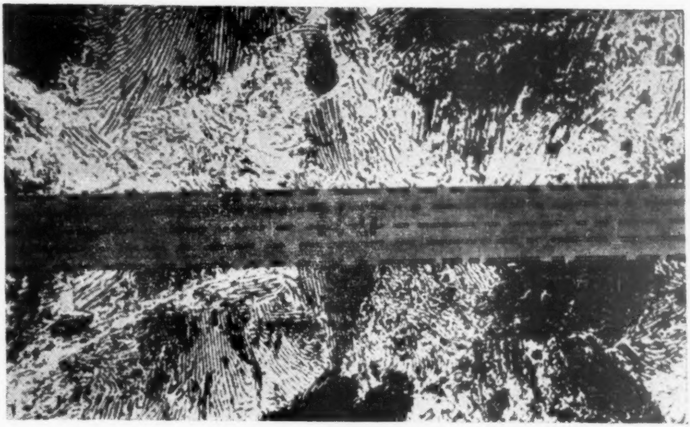


Fig. 25.

which should act as oil reservoirs in the event of failure of the oil film. There are innumerable data to show that the load carrying capacity of a bearing increases with the smoothness of the surfaces. The reason is, of course, in the case of rough surfaces that only the peaks are in contact giving very high local bearing pressures. A smooth surface has a much greater effective area of contact.

It is an accepted fact that under conditions of film lubrication the mating surfaces of a bearing are not in contact but are separated by a film of oil which is under pressure. (Fig. 24). Under lightly loaded conditions the nature of the surface finish is unimportant, but as the load increases the oil film becomes thinner and some of the peaks project through the films, contact similar peaks in the mating surface and are torn out, giving rise to local seizure on a very small scale. Further increase in load probably results in total seizure. As the peaks are reduced so the load carrying capacity increases, and in a good bearing an oil film only a few molecules thick is necessary. This means that the bearing clearances need only be extremely small.

This very thin oil film is under pressure, the sum of which exactly equals the load on the bearing. Consequently the oil will have a tendency to flow out of the bearing. Its flow will be greatly facilitated by deep scores or scratches which act as channels. In this respect Dr. Schlesinger has recently pointed out that oil grooves cut in a journal reduce its load capacity for exactly the same reason (Fig. 25).

We see then that theoretically a perfectly smooth surface is to be aimed at, but in practice the results have been disappointing, and we now find manufacturers steering clear of so called " mirror finished " surfaces. The previous theory assumes two important factors not always borne out in practice. The first is that there is always adequate lubrication. It is to be regretted that this is not always

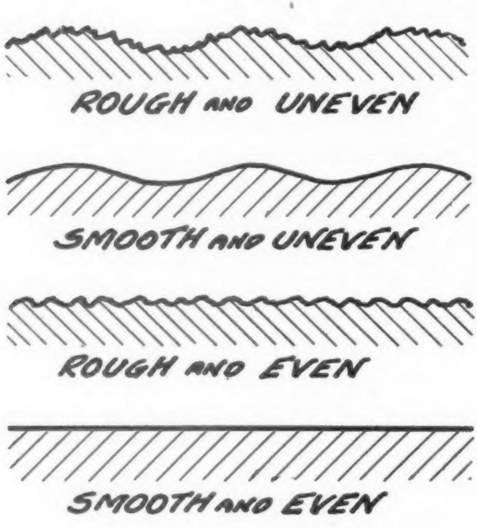


Fig. 26.—Rough versus Smooth.

the case, especially with reciprocating motions. Consequently metal to metal contact will occur at some period, and with an extremely smooth surface severe galling is likely to take place. In the rougher surface the scratches which are normally detrimental now act as oil reservoirs and minimise the area of seizure.

The second, and less recognised, factor is that surface quality is measured not only by smoothness, but also by roundness or flatness, as the case may be. It is quite possible to have a perfectly smooth surface (as measured by Profilmeter or other instrument) which is very uneven. (Fig. 26). If two such surfaces be run together the load would be carried only on one or two local points where extremely high pressures would occur. Unfortunately such is not the exception but the rule. We may make our surfaces perfect in every respect, but when assembled and under stress they are prob-

ably distorted from their original shape. A typical case is a cylinder bore, which on tightening the cylinder head studs and warming up to working temperatures becomes anything but round. Our only remedy in such cases is to fall back on the old way and rub off the high spots during the first few hours of the bearing life. A rough surface will bed up quicker than a smooth one, which may become ruined before it has bedded. For this reason piston rings are frequently given a rough finish on the periphery to facilitate rapid bedding. Thus we see that no rigid rule can be laid down for degree of finish required. Each case must be treated separately. It is general practice to make one of the surfaces fairly smooth and the other fairly rough. The smooth one should be the one less likely to distortion under working conditions. In the case of a journal bearing, the shaft is obviously the one to choose. During the running in period the shaft will remove the high spots of the journal, eventually producing a round and smooth surface.

Conclusions.

To sum up, the requirements of bearing surfaces are :—

(a) An even surface free from waviness or chatter.

(b) A surface finish as good as possible when conditions of lubrication and distortion have been considered.

(c) Freedom from subsurface defects due to overheating during machining, or embedded abrasives.

It is to be hoped that future design will minimise lubrication and distortion troubles, in which case we can look forward to machines which need no running in, and which will run for considerable periods without the necessity for maintenance.

In concluding here is an example of an achievement which should be a pointer to the future.

"Manufacturers in the electrical refrigeration industry, as long ago as 1931, offered a free, complete service guarantee for the first year after date of sale. This was made possible by extensive study and analysis in which all factors of design and production, from the laboratory to the final assembly, were correlated on a control plan. Specifications covered every phase of manufacture, including speeds and feeds used in operating each machine. Particular attention was given to the reduction of frictional wear, and to conserving the functional qualities of the material. Form accuracy was established at .0001 in. maximum, and surface finish smoothness within 2 to 4 microinches, r.m.s., for many operating parts in these hermetically sealed units. This original guarantee has since been increased to give five years for hermetically sealed units, and 10 years for open type units, with further experience in operation of quality control."

Let us look forward to the day when motor cars, machine tools, vacuum cleaners, and other articles of everyday life can be bought with a similar guarantee.

The author wishes to make due ackhowledgment to the following papers for the source of some of his information :

(*a*) "The Story of Superfinish," by Swigert.

(*b*) "The Iron Age series of Superfinish," by W. F. Sherman.

(*c*) "Produce the Specified Finishes by Honing," by L. S. Martz.

Research Department: Production Engineering Abstracts

(Edited by the Director of Research).

NOTE.—*The addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough.*

COMBUSTION, FURNACE.

Old Core Ovens Made New—A Worth-while Conversion to Gas. (*The Industrial Gas Times, November, 1943, Vol. VII, No. 74, p. 29, 2 figs.*).

Drawbacks of old ovens. Insulation. Value of recirculation. Heat transmission. Fresh air admission. Temperature control. Modernised core oven, showing some of the newly installed controls and equipment.

The Uses of Controlled Atmospheres in the Metal Industries. Part III —Commercial Atmospheres. (*Sheet Metal Industries, December, 1943, Vol. 18, No. 200, p. 2087, 5 figs.*).

Cracked ammonia. Percentage of hydrogen in partially burned cracked ammonia. Cylinder gases. Electrolytic hydrogen. Cracked hydrocarbons. Gas carburising furnace using gaseous carburising medium. Sulphur dioxide. Gas analysis. Pit type furnaces for hardening high-speed tools. Hardening. Tempering. Annealing. Normalising. Stress relieving. Treatment of hot-rolled material. Bright brazing. Nitriding. Gas carburising.

COOLANT, LUBRICANT.

The Lubrication of Driving Chains, by E. V. Paterson (*Mechanical World, 17 December, 1943, Vol. 114, No. 2972, p. 695, 11 figs.*).

The efficiency of a well-maintained roller type transmission chain, for example, should not be less than 98%. In order to maintain this efficiency and also to preserve the life of the chain, correct lubrication is vitally important. Chains are used: (1) for the transmission of power, (2) as connecting mediums for simple couplings, (3) for the conveyance of materials. Examples: Lineshaft drive enclosed in a chaincase with pump lubrication and integral oil sump. Typical arrangements for chaincases with pump lubrication. Application of snap drop oiler. Depth of oil required in chaincase. Transmission chain with segmental bush to collect and pump oil. Inverted tooth chain with rocker pin to eliminate sliding friction.

GEARING.

Equipment and Methods for the Production Heat Treatment of Gears. (*Mechanical World, 3rd December, 1943, Vol. 114, No. 2970, p. 645*).

A review of plant types and their uses, carburising materials, containers and operational procedure. Equipment. Heating and cooling rate. Carburising containers for gears. Carburising compounds for gears. Preparation for carburising. Case depth selection for gears. The carbon content of the case. The hardness of carburised gears. Relation of casehardening to machining operations.

MACHINE ELEMENTS.

Annular Ball Bearings—III, by R. Waring Brown. (*Power Transmission, December, 1943, Vol. 12, No. 143, p. 752, 9 figs.*).

Ball race rings. Full row ball bearings. Ball action in full row ball bearings. Ball bearings with cages. Annular ball bearings for thrust loads. Twin row ball cage. Single row ball bearing. Thrust capacity of annular ball bearings. Mounting ball bearings. The material required must be the finest procurable both in regard to its chemical composition and consistency and should have as high an elastic limit as possible. A typical material analysis is :—

C : 1.010% ; Si : 0.250% ; S : 0.019% ;
P : 0.020% ; Mn : 0.280% ; Cr. : 1.250%

MACHINING, MACHINE TOOLS.

Fine Boring Practice, by W. Boneham. (*Machinery, 16th December, 1943 Vol. 63, No. 1627, p. 673, 8 figs.*).

The principle of fine boring is a high spindle speed, a very fine feed and a light cut. Due to the exceptionally low machining stresses, very light clamping arrangements can be made, thus avoiding distortion of the component. Versatility of fine boring. Importance of spindle accuracy. Diameter variation by quill adjustment. To obtain the best surface finish, all conditions must be correct, i.e., the spindle must be in good condition, the correct shape of diamond used, and a fine, steady table feed obtained. The diamond shape has an important effect upon the surface finish obtained. Diamonds usually have a negative back rake and the clearance is kept to a minimum, according to bore diameter. Feed and surface speed. In the normal non-ferrous range of materials, very similar results are obtained as regards surface finish using the same diamond and speeds, etc.

Securing Fine Surfaces by Grinding, by H. J. Wills. (*Machinery, 16th December, 1943, Vol. 63, No. 1627, p. 690*).

The cutting action of any grinding wheel will vary with changes in the area of contact between wheel and work, the ratio of wheel and work speeds, the rate of traverse, and the amount of in-feed. Action between wheel and work. The selection of wheel and speeds. Procedure in starting grinding.

CHIPLESS MACHINING.

The Principles of Lubrication in Modern Deep Drawing Practice, by H. A. H. Crowther, P. D. Liddiard and K. I. Marwood. (*Sheet Metal Industries, December, 1943, Vol. 18, No. 200, p. 2099, 2 figs.*).

Metallic soaps. Soluble oils. Chlorinated hydrocarbons. Sulphur. Other chemical additive materials. Solid lubricants. Limitation of choice : chemical factors ; mechanical factors ; psychological and physiological factors ; method of dilution. The two most serious defects in any drawing operation are those due to scoring and fouling ; often they cause the article to be scrapped but what is much more serious, the tools, particularly the dies, are damaged. Effect of annealing on lubricants. Application of lubricant.

MANUFACTURING METHODS.

Broaching Oblique Holes, by W. Cooper, (*Machinery, 9th December, 1943, Vol. 63, No. 1626, p. 653, 4 figs.*).

Factors opposing easy production are : dimensional smallness of bore ; unusual length of circuitous perimeter in conjunction with small bore diameter ;

abnormal length of bore ; hard material and obliquity of the hole through the body of the component. Tensile safety factor. When a long perimeter has to be cut, broach teeth should be notched to break up the chips. Notches on the following teeth should then interspace those of the preceding ones. The component showing the square oblique hole which had to be broached. Milling preparatory to broaching. Broaching fixture. Details of broach and sequence of operations.

Simplifying Machine Setting, Part 2. (*Production and Engineering Bulletin, December, 1943, Vol. 2, No. 13, p. 587, 7 figs.*).

The problems of machine setting in factories, handicapped through shortage of skilled setters, should be considered at all stages in the manufacture of any product, from the design of the component to the final inspection. Maintenance of machine tools. Division of setting. Training of setters. Technical data for setters. Setting facilities.

Sheet-Metal Forming and Assembling, *by* W. Schroeder and T. H. Hazlett. (*Aircraft Engineer, December, 1943, Vol. XV, No. 178, p. 353, 57 figs.*).

Properties of common aircraft materials. Basic forming operations. Classification of actual parts. Forming equipment. Hydro-press forming with rubber platens. Limits for drawn boxes—24S-0 Alclad material. Stage used in multiple-cup tests. Comparative limits for single—and multiple-operation cups.

Temperature Control Gives True Leadscrews, by F. Schoeffler. (*The Machinist, 4th December, 1943, Vol. 87, No. 33, p. 90, 5 figs.*).

The Lodge and Shipley Machine Tool Company studied the existing methods of manufacture and inspection. Heat affects accuracy. For finish chasing precision leadscrews, the temperature of the room, the lathe, the cutting fluid and the work must be carefully controlled. Likewise, it is important to support the work close to the cutting tool. Precision leadscrews are inspected for lead errors and periodic errors with a special leadscrew checking instrument.

The Percival Proctor, by Wilfred E. Goff. (*Aircraft Production, January 1944, Vol. VI, No. 63, p. 5, 23 figs.*).

A light, wood trainer with post war potentialities. Construction and manufacture of the fuselage and wings.

The Halifax Undercarriage Bridge Casting, by J. A. Oates. (*Aircraft Production, January 1944, Vol. VI, No. 63, p. 21, 31 figs.*).

Foundry production methods. Machining sequence. Extensive use of horizontal boring machines tooled for quantity-production work.

MATERIALS, MATERIAL TESTING.

The Nature of Pure Metals, by J. F. Young. [*Mechanical Engineering, (U.S.A.), November, 1943, Vol. 65, No. 11, p. 795, 15 figs.*].

The structure of metals. The atom. Liquid metal. Solidification. Solid metal. Allotropic modifications. The grain structure of metals. Microscopic analysis. Optical microscope. Electron microscope. Refining and forming methods. Grain structure in castings. Cold working. Plastic deformation. Strain hardening or work hardening. Grain de-

formation and preferred orientation. Cold-work fractures. Recrystallization. Annealing. Grain growth. Hot working. Hot work fracture. Conclusion.

German Light Alloy Pistons, by C. W. Wilson. (*Met. Ind., 5th November, 1943, Vol. 63, No. 19, p. 298, Metallurgia, Nov. 1943, Vol. 29, No. 169, p. 33*).

Seven pistons, representing four engine types, have been examined for tensile and hardness properties, macro and micro-structure, and chemical composition. Six were of the eutectic Si-Al type containing additions of Cu., Ni., and Mg., the seventh contained 3.5% Cu, 1.75% Ni., 1.37% Mg. All had been press forged in dies from extruded blanks. It was concluded that a standardised manufacturing procedure for all pistons has been adopted in Germany.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Fatigue Characteristics of Rubber, by F. L. Yost. (*Trans. A.S.M.E., U.S.A., November, 1943, Vol. 65, No. 8, p. 881, 19 figs.*).

Repeated oscillations eventually will cause rubber or synthetics to deteriorate and crack from " dynamic fatigue." If maintained under constant stress just below its tensile strength, rubber will break from the high stress. This phenomenon is characterised as " static fatigue." Both vibration and loading are involved in practical applications of rubber and synthetics, and the material fails generally from a combination of these two causes. Data resulting from quantitive studies made on rubber and synthetic samples covering both types of failure are given. These are considered separately and then practical conclusions are drawn from the combination of the two.

Magnesium Alloy Fires are Preventable. (*Production and Engineering. Bulletin, December, 1943, Vol. 2, No. 13, p. 596, 2 figs.*).

Systematic swarf and dust clearance is the vital rule. Swarf hazards. Magnesium alloy dust. Three precautions, will minimise the risks : (a) strict cleanliness. (b) every possible source of ignition, including that from other grinding operations in the vicinity, should be totally eliminated. (c) smoking must be prohibited. In case of fire : water should never be used to extinguish magnesium alloy fires. A recommended extinguisher is a special proprietory powder which quickly smothers the flames. A preparation of short, natural asbestos fibre, mixed with graphite, dry sand (e.g., black moulding sand) ; or clean cast iron turnings, have also been found to be effective.

The Corrosion Resistance of Cladded Al-Zn-Mg Alloys, by W. Bungardt. [*L.F.F. (Germany), 20th July, 1943, Vol. 20, No. 7, p. 207/209*].

The corrosion resistance of Al-Zn-Mg alloys containing little or no copper (so called Hydronalium) is higher than that of Al-Cu-Mg. alloys of the Dural class, whilst their original strength is of the same order ($\sim$ 45 Kg/mm²). Dural cladded with Al. is however superior to the Hydronalium over long exposure periods, provided the material has been agehardened at room temperature. Hot age hardening on the other hand largely destroys the benefits of the cladding (copper diffusion from the parent Dural sheet into Al covering).

The question naturally arises whether the corrosion resistance of the Hydronalium alloys could also be further improved by cladding. Tests have shown that cladding with Aluminium produces no beneficial results in this case. If, however, a second Al-Zn-Mg alloy is used, a corrosion resistance

equivalent to that of Al. cladded Dural can be obtained in all cases, with the additional advantages that the cladded material can be used either in the cold or hot age hardened condition without effecting the corrosion resistance.

The sheet for cladding purposes has the following % composition.

Zn	Mg	Mn	Fe	Si	Al
2.68	.62	.18	.01	.07	rest

The composition of the parent sheet is given below, the 2 alloys only differing in Copper Content. The composition of Dural is given for comparison.

Alloy	Zn	Mg	Cu	Mn	Fe	Si	V	Cr	Al
1	4.35	1.52	1.55	.15	.12	.08	.12	—	rest
2	4.35	3.51	.27	.30	.08	.09	—	.25	,,
Dural	—	.99	3.42	1.00	.50	.44	—	—	,,

The corrosion tests covered a period of 200 days and were carried out by the DVL standard methods (Stirring and intermittent immersion both for plain and looped specimen—the latter for stress corrosion effect).

The specimen sheets were 1 mm. thick with a cladding of .05 mm.

The original mechanical properties of the cladded materials are given below:

Alloy	Condition	Yield point Kg/mm^2	Ultimate Kg/mm^2	Extension (10) %
1	a	27.0	42.3	21.1
	b	33.2	40.7	13.2
2	a	30.0	48.1	20.6
	b	42.5	48.6	11.0
Dural	a	26.6	43.7	19.7
	b	31.0	43.3	14.6

(a) cold aged—(room temperature).
(b) hot aged—(120° for 24 hours for alloys 1 and 2).
(160° for 72 hours for Dural).

Cladding for (1) and (2) —Special alloy already discussed.

Cladding for Dural—99.5% Al.

It will be noted that alloy 2 condition b is especially attractive for its high yield point.

(*Communicated by D.S.R., Ministry of Aircraft Production*).

The Effect of Nitrogen on the Properties of Certain Austenitic Valve Steels, by H. Cornelius and K. Fahsel. [*L.F.F.* (*Germany*), *Vol. 20, No. 7, 20th July, 1943, p. 210/216*].

The valve steels commonly employed contain about 15% Cr., 13% Ni, and 2% W (Tungsten). Recently austenitic Cr-Mn steels of much smaller Ni content have been proposed as a satisfactory alternative and it was claimed that the heat stability of such steels could be still further improved by small additions of N_2.

To investigate this matter, the authors prepared 14 samples of austenitic steels covering the following ranges of % composition.

C	Si	Mn	Ni	Cr	W	Ti	N_2
.43 .50	1.7 3.5	1.1 6.7	3.1 9.1	11.7 18.3	— 1.2	— .48	.02 .23

The variation in N_2 content was obtained by adding different amounts of Ferrochrome (containing up to 6% N_2) to the melt (high frequency furnace). The specimens were hardened by air cooling after forging (1050°C.) and subsequently tempered at 800°C. for 3 hours and again air cooled.

The tests were carried out both in this (so called original) state and after a further annealing at 700°C. for 200 hours followed by air cooling.

A comparison of the mechanical properties obtained in the original and annealed state enabled conclusions as to the stability of the austenitic structure to be drawn.

The authors conclude that the stabilising effect of N_2 on the austenitic structure of the steels is very small and that its introduction into the steel does not render possible any marked reduction in the Ni content as had been previously claimed. Under the most favourable circumstances the max. possible addition of N_2 (about .25%) is equivalent to about 2% Ni but in most cases considerably less (.5%). (Some previous investigators had claimed the replacement value of .2% N_2 to be the equivalent of 6% Ni).

In addition to the mechanical tests detailed above, the resistance of the steels to both rapid and slow rates of deformation was investigated. For the former, a special pendulum apparatus devised by the author was utilised, the experiments covering the temperature range up to 850°C.

For high rates of deformation (Pendulum test) the addition of N_2 is definitely beneficial at temperatures up to 400°C. At the working temperature of the valve (850°C.), however, the N_2 appears to have no effect. From the creep tests at 700°C., the authors conclude that the N_2 produces only a very small effect.

Such austenitic steels, especially when containing about .5% Ti, are sufficiently stable to replace the commonly employed valve steels of high Nickel and Tungsten contents thus leading to a considerable saving in these two constituents.

Communicated by D.S.R., Ministry of Aircraft Production).

MEASURING METHODS, APPARATUS.

Standard Control Limits. (*Production and Engineering Bulletin, December, 1943, Vol. 2, No. 13, p. 577, 8 figs.*).

Practical applications : (1) Dimensions of a microphone capsule case. (2) " Close-up " of the tools used on the press for " bumping " the case. (3) A sample of five components measured on comparator type gauges. Standard inspection record cards used. Holding scrap to a minimum.

Pressure Gauges—Their Installation, Maintenance and Repair, by J. R. Fawcett. (*Mechanical World, 24th December, 1943, Vol. 114. No. 2973, p. 743, 13 figs.*).

Instruments are of little use unless they are properly installed, regularly serviced and calibrated. Deadweight pressure gauge tester. Screw press for use with master gauge. Mercury column for testing gauges. Bourdon gauge. Steel-

tube hydraulic gauge. Pressure gauges should be graduated to twice the working pressure where this is up to and including 500 lb. per sq. in. and for pressures exceeding 500 lb. per sq. in. to one and a half times the working pressure so long as the maximum graduation is not less than 1000 lb. per sq. in. The gauges must be mounted on a support which is as free as possible from vibration. Schaffer diaphragm gauge. Causes of pressure gauge failure. Adjusting a pressure gauge. Major repairs : bourdon tubes, movements and new dials are the parts which are most likely to need replacement.

Bearing Inspection Without Contact. (*The Machinist, 4th December, 1943, Vol. 87, No. 33, p. 86, 8 figs.*).

Lead-indium plating is easily marred or scratched ; hence Wright checks the critical I.D. of master-rod bearings by means of the air-gap gauging principle. To control the flow of air from the two nozzles, or orifices, the shop air pressure is reduced by two regulators and line fluctuations are ironed out by a restriction tube in the gauging spindle. Two bearings are stacked in a fixture for lead plating to avoid uneven plate thickness, particularly a thicker deposit at the ends.

Precision Tests for Ball Bearings, by C. E. Stoodly. (*The Machinist, 18th December, 1943, Vol. 87, No. 35, p. 92, 5 figs.*).

Carefully planned inspection devices show the radial play, end play and sensitivity of ball bearings for instruments. When using the end-play measuring device the load is applied to the inner race. With the inner race held fast, the load weight is applied and released to determine radial play. The sensitivity checking device has an electric clock motor drive and an indicator calibrated in inch-ounces.

Three-Wire Measurements of Screw-Threads—I and II, by J. F. Heaton. (*The Machinist, Reference Book Sheet, December, 1943, Vol. 87, No. 35, p. 96a, 1 fig.*).

Tables which avoid the necessity for calculation if " best wires " are used in measurement of American National coarse and fine series threads. Best wire is the size of wire that will contact the side of the thread at the pitch diameter. Class 1. Loose fit, American National Coarse-thread series. Class 2, free fit ; class 3, medium fit ; class 4, close fit.

Automatic Temperature-Recording Control System, by M. E. Moore. (*Trans.A.S.M.E. (U.S.A.), November, 1943, Vol. 65, No. 8, p. 809, 11 figs.*).

The automatic temperature-recording system developed by the Douglas Aircraft Company, Inc., is described. The system provides for the measurement of any number of points in groups of twenty-four each. The adaptation of this system to any automatic temperature-recording device is discussed, and the requirements of such a device are stated. Design considerations are covered, and the construction and operation of the system described.

PLASTIC MATERIAL, POWDER METALLURGY.

Powder Metallurgy for Production, by R. P. Koehring. (*The Tool Engineer November, 1943, Vol. XII, No. 11, p. 105, 4 figs.*).

At the Morain Products Division of the General Motors Corporation, a variety of products manufactured includes oil pump gears, self-lubricating bearings, highly irregularly contoured cams, diesel injector filters, and fatigue, resistant babbitt lined steel bearings. Metal powder is hopper fed into dies, pressed into briquette form, sintered in temperature and atmosphere controlled

furnaces, and, if necessary, re-sized in a final pressing operation. Secondary operations, such as machining, are only necessary when tolerances are required which are closer than those which can be controlled in the sintering operation in view of the dimensional changes which occur during this heat treatment. Typical parts produced by powder metallurgy.

Copper-Lead Bearings by Powder Metallurgy, by W. D. Jones. (*Metallurgia, October, 1943, Vol. 28, No. 168, p. 255*).

Gives results of extensive tests on Cu-Pb alloys. (Prepared from powders) containing 16.5, 25.5, and 36.5% Pb., from which it is concluded that the optimum conditions for the production of nonporous products are sintering at 650-850°C., with pressure about 5 tons/sq. in., followed by coining pressure 10 tons /sq. in.

(*Communicated by the British Non-Ferrous Metals Research Association*).

SHOP MANAGEMENT AND ADMINISTRATION.

Management Problems in Judging Quality Conformance in the Inspection Function, by J. M. Juran. (*Mechanical Engineering, (U.S.A.), November, 1943, Vol. 65, No. 11, p. 805, 1 fig.*).

Fact finding distinguished from judgment of conformance. Acceptance of material not conforming with functional limits. Acceptance of material not conforming with manufacturing limits. Acceptance of conditions of poor workmanship. Borderline product. Conflicting measurements. Conflicting interpretations on non-numerical inspection items. Division of responsibility between inspector and supervisor. Rejections. Summary. Judging manufactured product for conformance with the quality specification force for all of the responsibilities which go with the exercise of a judicial function. A clear understanding of the facts, a clear understanding of the quality law, and a lack of bias are all fundamental to this undertaking. This judicial act often leaves to the inspector a broad band of individual discretion.

Practical Applications of Quality Control, by W. A. Bennett. (*Machinery, 23rd December, 1943, Vol. 63, No. 1628, p. 701, 3 figs.*).

Quality control first operates as a control of production, to ensure that only a minimum amount of selection of good from bad products is necessary, secondly, it enables the producer to appreciate the quality of the bulk by a series of samples. This allows him to establish conditions by which we can guarantee a known level of quality. The framework of supposition. The machine product average. Method of approach. Quality control in application. Questions of setter's limit. Smaller sampling scope. Automatic machine performance. Fraction defective. Application to machine products. How a con rol chart for fractional defect is plotted.

Subcontracting Made to Work, by J. Haydock. (*The Machinist, 18th December, 1943, Vol. 87, No. 35, p. 83, 3 figs.*).

American Type Founders have created a separate division to supervise the manufacturing activities of outside plants on sublet orders. Control of these operations covers tools to finished products. The flow chart on a typical war product shows the shipment of parts to the prime contractor's assembly plant and thence to the government procurement agency.

SMALL TOOLS.

Increase Punch Life. (*The Tool Engineer (U.S.A.), November, 1943, Vol. XII, No. 11, p. 72, 4 figs.*).

Development of tungsten-carbide punch and die inserts permits economical slotting and notching of rotor and stator laminations on limited production. Punch and die design. Overall tolerances.

Industrial Diamonds, by Dr. D. F. Galloway. (*Engineering, 3rd December, 1943, Vol. 156, No. 4064, p. 441, 22 figs.*).

Useful criteria for the selection of diamonds for specific industrial applications, are (1) hardness, (2) flaws, (3) inclusions, (4) thermal properties, (5) cleavage, (6) twinning, (7) colour and (8) the aggregation of crystals other than twinning. Relative hardness of various materials, including carbides and diamonds. Comparison of thermal conductivity and expansion of diamond and other materials. Methods of setting diamond tool tips ; hot setting, cold setting and combined hot and cold setting. Hot setting includes casting and brazing. The most usual method of cold setting used for fixing diamond turning-tool tips to their shanks is by clamping.

STANDARDISATION.

Standardisation of Motor Dimensions, by H. Marryat. (*The Journal of the Institution of Electrical Engineers, December, 1943, Vol. 90, Part II, (Power Engineering), No. 18, p. 369, 2 figs.*).

In this paper the author proposes that British manufacturers should collectively standardise overall and fixing dimensions of commercial electric motors covering a range of approximately 1 to 50 h.p. The advantages quoted for standardisation comprise a saving in drawing and erection costs, more prompt deliveries, avoidance of delays, fewer spares, saving of stores space, interchangeability and ease of replacement in the event of breakdown. Objections which have been advanced against the proposal are considered and answered. The degree of standardisation already achieved in the U.S.A. is considered, and the paper concludes with remarks upon the possibility of standardising control gear.

SURFACE, SURFACE TREATMENT.

Metal Spraying with the Gas Pistol (Swedish), by S. Brennert. (*Teknisk Tidskrift, 14th August, 1943, Vol. 73, No. 33, Bergvetenskap No. 8, p. B61*).

A review of metal spraying, particularly with gas pistols, discussing the mechanism of the process, effects of various factors on properties of coatings, uses and relative cost compared with other methods of application, and probable future developments ; based on a survey of the literature together with experience in Sweden. Metal spraying was first taken up in Sweden in 1930 and some hundreds of installations are now in use. The author expects future developments in Sweden to follow on established lines, viz : zinc alone or as a basis for painting ; aluminium in building and food industries, and with subsequent annealing for enhanced scaling resistance of hot parts ; and steel for building up worn parts as commonly applied in U.S.A.

(*Communicated by the British Non-Ferrous Metals Research Association*).

WELDING, BRAZING, SOLDERING.

Resistance Welding Practice by means of a Film with Synchronised Commentary. (*Sheet Metal Industries, December, 1943, Vol. 18, No. 200, p. 2157, 14 figs.*).

The excellent illustrations show processes in common use ; spot, projection, seam, butt and flash welding.

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Flash-welding of Alloy Steels, by H. W. G. Hignett and G. Mayer. (*Welding, September, 1943, Vol. 11, p. 399*).

A brief resumé is made of the three metallurgical operations essentially involved in flash-welding (heating, flashing, and welding and forging), as a basis for discussion of the differences in behaviour of mild steel and alloy steels in the flash-welding operation. With mild steels, wide tolerance is permissible in the conditions obtaining in each of the three operations. For alloy steels, however, the optimum range of conditions is narrow, and can be consistently maintained only by using machines permitting fully automatic control of pre-heating, flashing and upset. In some cases, post-heating is also required.

(*Communicated by the Nickel Bulletin*).

Building-up and Hard Surfacing by Welding, by William Andrews. (*Welding, December, 1943, Vol. XII, No. 1, p. 9, 3 figs.*).

A distinction must be made between building up to repair or replace worn or corroded metal and the incorporation of weld metal of special properties in the original design of an article. The building-up or surfacing operations in which welding is employed may be considered as serving three main ends : (a) repair or reduction of abrasion in all its various forms, (b) repair or reduction of corrosion of all types, (c) reclamation of faulty material arising from poor workmanship or other reasons. Effect of arc conditions. Metals available for arc welding. Special-purpose electrodes. Oxy-acetylene welding. Application of welding for corrosion resistance. Special classes of welding. Welding of non-ferrous metals. Welding of special alloys.

Hard Surfacing Applications and Techniques. (*Society of Automotive Engineers (U.S.A.), Pamphlet, 1943*).

Prepared for the S.A.E. for the Vehicle Maintenance Section, Division of Motor Transport, U.S. Office of Defense Transportation. It outlines oxy-acetylene and resistance welding methods of applying the hard surface ; selection of surfacing material ; operator training ; costs ; instructions for hard-facing a number of automobile parts.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Fabricating Welding-Quality Elektron, by W. K. B. Marshall. (*Met. Ind., 29th October, 5th, 12th, November, 1943, Vol. 63, No. 18—20, pp. 274, 290, 306*).

An authoritative article in three parts. I—Protection and general handling (including fire risks). II—Working (temperature, heating, bending, beating, wheeling, pressing and die-forging). III—Gas welding (general technique, flux removal, metallurgical factors, covering power of the flux, welding speed, length of run), spot welding, machining, and finishing.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Chain Cables, by T. Scott Glover. (*Trans. of the Inst. of Engineers and Shipbuilders in Scotland, December, 1943, Vol. 87, Part 2, p. 11*).

Comparative sizes and weights per 15-fathom length of iron and steel cables with one joining shackle. Heat-treatment furnace. 800-KVA flash-welding machine. Solid and welded links. Links before and after removing " upset " metal. Section of welded link showing grain flow. Components of welded joining shackle.

Spot Welding of Aluminium Alloys in Aircraft Construction. (*A. V. Seerlender Inter Avia (Switzerland), 9th August, 1943, No. 879/80, pp. 1/7*).

The welding of heat hardened Al.-Alloys in aircraft construction is attractive from the point of view of production if the dangers due to softening of the material at the seam and change of structure of the sheet in the neighbourhood of the weld could be overcome. Spot welding appears to offer special advantages in this connection since the heat is localised and only applied for a short period (~ /10 sec.). The subsequent cooling is very rapid (heat conduction to the surrounding material) and the small size of the annular softened region should not produce a serious drop in strength. Test figures show that this is indeed the case and that provided the welding machine is controlled properly spot welds of high and consistent strength can be obtained.

According to the author, the following average shearing strength in Kg. per spot should be obtainable under these conditions.

Thickness of sheet mm.	Metal			
	Pure Al (hard)	Avional (Al-Cu-Mg) age hardened	Anticorodal (Al-Mg-Si) age hardened	Peraluman (Al-Mg) soft
.5	50	100	100	100
1	100	190	150	200
2	220	320	380	480
3	250	430	480	—

As regards the spacing of the spots, similar considerations to those holding for riveting apply. The closer the spacing, the greater the proportion of current lost by shunt action of the neighbouring spot. For 1 mm. gauge, a 20 mm. spacing is recommended.

For sheet gauges up to 1.5 mm. and in the absence of excessive fatigue loads, spot welding thus may replace the much more expensive riveting in aircraft construction besides speeding up production considerably. This however, only applies if the process can be accurately controlled under practical conditions. Lack of such control in the past has caused the strength of individual spot welds in light alloy to vary in the ratio of 5 to 1 in practice (as distinct from laboratory results), leading to a rejection of the process in this important field, whilst the spot welding of iron sheet has already been adopted extensively.

The main difficulty with light alloys is the close approach of the necessary welding temperature to the melting point of the alloy, combined with the great heat conductivity of the material. In the case of steel, the melting point exceeds the welding temperature by 400°C.

Besides time (vc number of cycles) and current, the contact pressure between the electrode and the sheet requires careful control. Excessive pressure dimples the metal whilst insufficient pressure causes arcing and highly undesirable alloying of the copper electrode with the sheet.

For 1 mm. sheet, the author suggests a contact pressure of about 250 Kg using 5 mm. electrodes. This pressure is usually applied hydraulically and maintained constant during the welding period.

The article concludes with a useful bibliography (18 items).

(*Communicated by D.S.R., Ministry of Aircraft Production*).

Silver Alloy Brazing with High Speed Localised Gas Heating, by J. I. Butzner. [*Iron Age (U.S.A.), 23rd September, 1943, Vol. 152, No. 13, p. 38*].

Selas ceramic gas burners are used in this method, and Easy-Flo and Sil-Fos brazing alloys. The equipment and brazing procedure are described here, together with numerous examples.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Low-Temperature Brazing with Silver Alloys, by A. J. T. Eyles. (*Mechanical World, 3rd December, 1943, Vol. 114, No. 2970, p. 642, 6 figs.*).

Silver alloy brazing is actually the cheapest method of making many of the joints required in the various metal working industries, where superior strength neatness, ductility, leakproof joints and resistance to bending stresses, vibration and corrosion are primary considerations. The strongest brazed joints are invariably obtained when they are closely fitted and a much smaller quantity of the silver alloy is used than the filleted or V-joints which are common to ordinary brazing alloys or solders. Examples : Silver brazing longitudinal seams on small boilers ; brazing a steel " T " pipe to a brass cylinder ; Silver brazing a copper tube into a cast brass flange ; low-temperature silver brazing very thin brass components ; production silver brazing on brass fuel trap units.

Solders and Soldering Practice, by W. E. Boare. (*Sheet Metal Industries, December, 1943, Vol. 18, No. 200, p. 2129, 4 figs.*).

Bit soldering and blowpipe soldering of miscellaneous parts in radiator subassembly operations. Solder sticks metals together by filling the joint spaces with a metallic substance that adheres tightly to the members of the joints. Composition of solder. Fluxes. The soldering process. Cleaning and fluxing. Electro-tinning. Fluxing of the joint. Resin fluxes. Paste fluxes. Heating the joint. Soldering iron types. Properties and grades of solder. Photomicrograph showing the bond between soldered steel. Strength properties. Antimony in solders. Solders and tin economy. Manipulative technique. Substitute solders.

WELFARE, SAFETY, ACCIDENTS.

Am I Injuring my Eyes ?, by R. Grange. (*Industrial Welfare, November-December, 1943, Vol. XXV, No. 291, p. 174, 3 figs.*).

Industrial eye risks can be divided into two main classes—those received when welding, and those from general hazards. Gas welding. Electric arc welding. The welder's mate. This man is working as near the arc as the welder himself, but cannot be given a very dark welding glass because if he wore this he could not see to hold the plate in the correct position. The best solution is to supply goggles fitted with a glass called " Infrex." The spectacle type goggle, suitable for light grinding. The " Overglass," suitable for welding, grinding and like operations.

Experiments in Rehabilitation. (*Industrial Welfare, November-December, 1943, Volume XXV, No. 291, p. 166*).

(1) The Vauxhall scheme. (2) Rehabilitation at the Austin Motor Works. The rehabilitation shop. Payment and incentives. Typical cases ; (1) Example of occupational therapy and progression from job to job. (2) Alternative work for patents awaiting treatment who would normally be unemployed. (3) Retraining of permanent cripples. Co-operation with other bodies.

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